W.P.

5-20-00:

Janine -

Here is an item on the Pacific Islands (Guam) that I missed.

Bryan

Guam Bureau of Planning

BUREAU OF PLANNING
GOVERNMENT OF GUAM
AGANA, GUAM

FUTURE POWER PRODUCTION AND TRANSMISSION

ALTERNATIVE PLANS

GUAM, U S A

Prepared for the Government of Guam

by

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Copy of letter of transmittal

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June 2, 1977

Mr. David Bonvouloir
CZM Coordinator
Bureau of Planning
Government of Guam
Agana, Guam 96910

Dear Mr. Bonvouloir:

The following is in reference to your letter of 3 May 1977, resulting in the following additions to our report submitted on 21 April 1977:

Comments and Discussion, pages 1 through 7
Section I-1
Section I-1-1
Section IV-1
Section V-1
Section V-1-1
Section VII-1

Copies of the new revised report are enclosed in duplicate. These copies now supersede report previously submitted by letter of 21 April 1977.

After perusal of the above material, please feel free to contact the undersigned if you should find need for further amplification or additions. We remain at your service and shall be glad to cooperate in support of your requirements.

Sincerely yours,

W F Pinckert
WALTER F. PINCKERT
Engineering Consultant

WFP/afm
encls: (2)

F O R E W O R D

The contents of this report are primarily centered around existing and future progressive expansion of facilities that will be needed to produce energy for the people of Guam and the military establishments. Included are progressions developed to show (1) optimized capability of new plant as needed to supply future power demand (2) annual projected increase in estimated KWH generation (3) corresponding fuel oil needs (4) pass thru of fuel oil cost to consumers and (5) fuel oil refinery capability on Guam and other facets related to power production and future projection.

COMMENTS AND DISCUSSION

The following amplification notes refer to letter of 3 May 1977 from the Coordinator, Coastal Zone Management Section, Bureau of Planning, Government of Guam.

Land holdings, leases, rights-of-way

The planned expansion of main and primary power transmission lines is shown on GPA Drawing No. B-74-023. The dates given are subject to change depending on the magnitude and direction taken by load growth. It is suggested that it would be good policy for the government to take options or lease rights-of-way at the earliest practicable date for all lines planned to be in operation 5 years hence. There is no alternative to early acquisition of rights-of-way, it will pay dividends in avoiding delays and cost of lease holds. Aerial surveys will prove invaluable in site feasibility studies and plotting of alternate routes.

Regulations and Permits

1) Corps of Engineers Permits

   Except for a permit stipulation on building a small boat launching ramp and trailer car parking area, GPA has no outstanding U. S. Army Corps of Engineers permit obligations respecting the siting of the Cabras Steam Power Plant.

   In the case of the Tanguisson Power Plant site, the U. S. Army Corps of Engineers permit was a matter resolved between the Corps and the Navy, since construction of this facility was initiated and completed by the Navy.

2) The Clean Air Act

GPA's Federal EPA compliance schedule for sulfur dioxide was amended by Court decision dated 23 August 1976, this decision extended GPA's compliance date calling for either stack gas scrubbers in operation by 31 July 1981 or low sulfur fuel oil by Agusut 1979. This is in reference to the Cabras Steam Power Plant, which comes under Federal New Sources Performance Standards.

3) Water Pollution Control Act

GPA applied for and was qualified under the "less stringent" regulations of the Federal Water Pollution Control Act. Under "less stringent" GPA must submit plans for review by EPA, 9th Region showing measures proposed for no increase in temperature of the waters discharged from the Cabras or Tanguissòn Power Plants above the normal temperature of the receiving waters. It is a further requirement, unless the law is amended, that zero temperature difference be accomplished by 1981.

Load Shedding (reference Section V-1)

Since GPA has no consumers taking large blocks of power that could be committed to an interruptable load schedule, resort must be had to power outage rotation by areas within districts served from the principal load distribution centers. Currently reserve for maintenance and forced outages has, it is understood, been established as the sum of the largest and next largest turbine-generator in the system, i.e. one 66 MW Cabras unit plus the power barge Inductance; 66 + 28 MW respectively or a total of 94 MW.

Major power outages (reference Section V-1)
Major power outages are usually caused by line faults of sufficient magnitude to trip out main generators and problems related to getting main generators restored to the line. For the past several years line faults per se have caused outages of relatively short durations, minutes to a matter of about 4 hours.

Rate structure anf fuel oil price pass-through (ref. Page 15, Sec. III)
Rate structure and application of fuel oil price pass-through is described under "Fuel oil pass thru rate per KWH" on page 15 of this report.

Electric power needs beyond the year 2000 (ref. Page 11, Section II)
Beyond the year 2000, in 2005 plans must be ready for the installation of the first unit in the 150 MW size, assuming a continuing load increase of 5% annually. Since the Tanguisson and Cabras units will have reached retirement age a second 150 MW unit must follow shortly after the first 150 MW unit is installed. This will carry power needs beyond the year 2010.

Life expectancy of present fuel oil pipe lines (ref. Section IV-1)
This item is covered in Section IV-1 of this report. Note that all pipe lines installed underground are cathodically protected and should therefore last for 40 years, the expected life span or longer.

Market logistics for GORCO products (ref. Section V-1-1)
Logistics, land use and other developments are discussed under Section V-1-1 of this report.

Solar Sea Power (ref. Section VII)
As mentioned in Section VII of this report the old Navy quarry site on Cabras Island could probably serve as a land based solar sea power plant site. In the case of Cocos Island or Facpi Point, site development would involve reclamation of reef area by dredge operation. Feasibility studies should be made to pinpoint the most favorable site with respect to environmental impact and economic factors.

Transmission Line Size
The existing 115 KV transmission line and planned expansion will be ample in voltage for Guam's power needs to the year 2000. Right-of-way width depends on conductor configuration, which will probably continue as at the present time with two-circuit vertical configuration. In this case the line right-of-way will be approximately 100 feet in width and greater depending on length of span and height of tower.

Transmission line towers, conductors and insulators are generally given a service life of 60 years, although the actual expected service life could exceed this figure by many years. GPA will need to take action at an early date to acquire right-of-way for extension of the existing power transmission system.

The same right-of-way can be used jointly for overhead power transmission and underground fuel oil pipe lines. This would also apply to underground fuel oil pipe lines and underground power lines assuming that there is adequate separation between fuel lines and power cables. Isolation is usually achieved by installing underground power cables on one side of a highway; fuel lines on the opposite side.

Other items in reference to transmission line rights-of-way are covered under the previous paragraph titled "Land holdings, leases, rights-of-way".

Visual impact of future transmission lines (ref. Section I-1-1)

Discrete routing of power transmission lines can often avoid objectionable skyline and other exposed effects. Life cycles of the new plastic forms of underground cable insulation have not been historically determined except through life acceleration tests, thus a limit of 20 years is currently assumed, although this may not be realistic; only time will tell. Also, note Section I-1-1 on the esthetics of overhead power transmission lines, and comparative costs of underground lines.

Improvements in environmental and esthetic impacts
(reference Section I-1-1)

It is believed that discrete routing of high-tension transmission lines including, where appropriate, use of line supporting structures of stream lined, unencumbered design will result in public acceptance without severe criticism or obvious ruthless scarring of the environment.

Real Property Resources (ref. Page 11, Section II)

With reference to real property resources, GPA is fortunate in that the Cabras Plant, within its present boundaries, can be expanded by the addition of 2 additional steam turbine-generators. After the Cabras area is fully occupied GPA can move into the Piti Power Plant area, owned by Navy, for installation of additional generating plant capable of supplying power to the year 2000. Reference thereto is contained in Section II, page 11 of this report. It is, also, to be noted that GPA owns real property for fuel oil bulk storage tanks to take care of needs to the year 2000.

Major changes in fuel oil pipe line systems (ref. Page 18, Section IV)

No major changes or additions will be required in fuel oil delivery or transfer pipe line systems to take care of power plant fueling needs to the year 2000.

GORCO's real property assets vs production (ref. Section V-1-1)

In reference to GORCO refinery's real property assets in relation to production capability reference is made to Section V-1-1 of this report.

Routes proposed for future extension of power transmission lines

Extensions of transmission lines are marked on GPA drawing No. B-74-023, included are dates when the indicated extensions will probably take place.

Load growth projection weights (ref. Page 21, Section V)

The weights given to load growth projection may be off the mark in the assignment of unit values in some instances, however, it is felt that in the plus or minus aggregate the sum may balance. Obviously 2% growth is too high a mark if nothing is going to be done to encourage tourism, it will continue to slide downhill with a negative mark for load growth. Tourism as an industry is very competitive, but in spite of this if made attractive it is self-perpetuating. At the present, the reverse is true on Guam, e.g. a safe well lighted broad-walk along Tumon bay beach is long overdue, neither is beach frontage being improved, bicycle trails or non-existent, etc. Tourists continue to be victimized by thieves and thugs in or out of tourist hotels. Work done for tourists in improving beach fronts, etc. would also benefit local residents. If overdue improvements are not gotten underway soon, more hotels may close down.

Life expectancy of power generating units (ref. Section I-1)

Values of life expectancy are given under Section I-1 of this report.

I N D E X

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I. Maps and drawings of power related facilities, enclosures to letters as follows:

Letter dated 8 December 1976

a. NAVFAC Drawing No. 7.900.500. This drawing gives the location of the Navy owned and operated Piti power plant and adjacent fuel oil storage tanks. The building housing the steam turbine-generators is numbered "4910". It contains 3 x 11,500 KW De Laval turbine-generators and 2 x 22,000 KW Allis-Chalmers turbine-generators. All units are in serviceable condition except one of the De Laval 11,500 KW units, which is beyond economical repair.

b. Drawing No. 70-38-3 is the boundary survey of the Cabras steam power plant before site development was undertaken.

Drawing No. 1001-5 is the plot plan of the Cabras steam power plant.

The above mentioned facility consists of 2 x 66,000 KW, 1800 psig, 1000/1000 deg F reheat steam turbine-generators. The site development included accommodations for installation of 2 future turbine-generators of equal or approximately 50% greater capacity. The Cabras steam power plant is wholly owned and operated by the Guam Power Authority.

c. Drawing No. 73-88-01 is the boundary survey of Guam Power Authority's bulk fuel oil storage tanks.

Drawing No. GPA 99-74 is the plot plan of GPA's bulk fuel oil storage tanks. This facility consists of 2 x 268,600 bbl fuel oil storage tanks, each 200 ft. in diameter by 48 ft. in height. The land area is ample in size for the installation of two additional future storage tanks of the same capacity.

d. Drawing No. 05-008 is the plot plan of the mooring facility for the power barge "Inductance". The power barge is owned by the U.S. Army, Corps of Engineers, made available by lease agreement to the Guam Power Authority under administrative control of the Navy/GPA power pool agreement.

The barge houses 2 - each 15,000 KW equivalent steam boilers and 1 x 30,000 KW turbine-generator.

e. Drawing No. 1102205 is the plot plan of the Tanguisson power plant. This installation consists of 2 x 26,500 KW steam turbine-generators. Unit No. 1 is owned by the Navy, unit No. 2 is owned by the Guam Power Authority. This facility is operated by GPA under the joint GPA/Navy power pool agreement.

Letter dated 2 March 1976

a. Navy map showing route of the 8-inch fuel oil pipe line from the Navy's Sasa Valley pumping station to the Tanguisson Power Plant. Encl No 1

b. Navy map showing fuel oil pipe lines from fuel off-loading piers to fuel oil transfer pump station and storage tanks. Encl No 2

c. Navy plan and profile drawings, fuel pipe lines from piers to pump house. Three sets, drawings No 474046, 474047, and 474048. Encl No 3

d. Map showing proposed line of easement for GPA's proposed 20-inch fuel oil pipe line from Navy Fuel Wharfs "D" and "E", Apra Harbor. Encl No 4

e. Plot plan of GPA's main power transmission lines.

Letter dated 11 April 1977

Drawing No. B-74-023, GPA Distribution, Island-wide Power System.

I-1. Generating station capability, date on stream, expected life and real property interest

Island-wide power generating stations are enumerated as follows with respect to (1) nominal capability (2) approximate date on stream (3)* remaining expected life and (4) real property vested interest:

Cabras Steam Power Plant

(1) 2 x 66 MW units = 132 MW

(2) Unit No. 1 on stream August 1974; No. 2 on stream June 1975.

(3) 30 years from on stream date Unit No. 1 will come to the end of its allotted service life, i.e. in the year 2004; No. 2, 2005.

(4) Cabras plant site is on land that was originally submerged; reclaimed by land fill. Title thereto granted to Guam Power Authority by an act of the Congress, USA.

Piti Steam Power Plant

(1) 2 x 22 MW units and 2 x 11.5 MW units = 67 MW

(2) 2 x 11.5 MW units went on stream in 1951; 1 x 11.5 MW unit in 1955. 2 x 22 MW units in 1964. 1 x 11.5 MW unit, because of accidental damage, is out of service. Cost of repair may preclude restoration to serviceable condition.

(3) End of allotted service life of the 2 x 11.5 MW units (30 years) in 1981; the 2 x 22 MW units in 1994.

(4) Piti Plant site is on land owned by Navy.

Tanguisson Steam Power Plant

(1) 2 x 26.5 MW units = 53 MW

(2) Unit No. 1, on stream October 1971; Unit No. 2, December 1972.

(3) 30 years from on stream date Unit No. 1 will come to the end of its allotted service life, i.e. September 2001; Unit No. 2, September 2002.

(4) The Tanguisson Power Plant site is on land acquired thru purchase from owners by Guam Power Authority.

Tamuning Diesel Power Plant

(1) 4 x 2 MW units = 8 MW

(2) These units went on stream in April 1970. Currently because of the high cost of diesel fuel oil and maintenance they are used only as a source of emergency power.

(3) 20 years* from on stream date these units will have reached the end of their service life, i.e. 1990.

(4) The Tamuning Diesel Power Plant is on land acquired thru purchase from owners by Guam Power Authority.

Dededo Diesel Power Plant

(1) 4 x 2.0 MW diesel units = 8 MW

(2) These units went on stream in October 1972. Currently because of the high cost of diesel fuel oil and maintenance they are used only as a source of emergency power.

(3) 20 years from on stream date these units will have reached the end of their service life, i.e. 1992.

(4) The Dededo Diesel Plant is on land acquired thru purchase by Guam Power Authority.

Power Barge Inductance

(1) 1 x 28 MW steam floating power plant. This plant is leased to Guam Power Authority by the Navy.

(2) It has been on stream at various locations since 1943.

(3) This facility reached the end of its allotted service life in 1973. Because of low KWH output in relation to fuel oil input it is used primarily for standby and emergencies.

(4) The barge is moored adjacent to Navy owned land. However, the mooring wharf was built and is owned by the Guam Power Authority.

*Expected life of 30 years for steam power plants and 20 years for diesel power plants conforms with regulations of State and the Federal Power Commission.

I-1-1. Esthetics of overhead power lines.

With the advent of polyvinylchloride and other plastic insulations considerable impetus was given to the installation of underground power transmission and distribution lines. The choice is primarily a matter of cost vs esthetics, opinion polls are overwhelming in condemning overhead line construction as esthetically objectionable, not in structural concept but as environmentally inharmonious.

Considerable success has been achieved through unfettered, balanced design of structures and transmission towers, including the routing of power lines to produce a low environmental profile, thereby avoiding an offensive skyline silhouette. The cost of these measures is, of course, greater than conventional design, nevertheless, it has become the accepted practice of the industry to be mindful of esthetic values, often with startling results in betterments at little additional cost. In heavily populated urban areas todays power distribution lines have no other place to go except underground.

In suburban housing areas and shopping centers it is becoming almost universal practice, primarily for esthetic reasons, to install power lines underground. The added cost of going underground, which averages approximately 2 to 3 times the cost of overhead lines, is passed on as part of the site development cost of the project.

II. Power demand projection to meet needs of the military and local economy, Guam, USA.

Capability, Guam Power Authority and Military owned power plants:

Cabras SPP*, 2 x 66 MW** units, owned by GPA	132 MW
Piti SPP, 2 x 22 MW and 2 x 11.5 MW units, owned by Navy	67 "
Tanguisson SPP, 2 x 26.5 MW units, Unit No. 1 owned by Navy; unit No. 2, GPA	53.0 "
Tamuning, 4 x 2.0 MW diesel units, owned by GPA	8 "
Dededo, 4 x 2.0 MW diesel units, owned by GPA	8 "
Inductance Power Barge, 1 x 28.0 MW Steam unit leased to GPA by Navy	28 "
System Total	296.0 MW
Maintenance outage, largest unit in system	66.0 "
Total remaining	230.0 MW
Forced outage insurance, next largest unit in system	28.0 "
Remaining to meet demand	202.0 MW
Current demand	150.0 "
Remainder to meet projected load growth	52.0 MW

*SPP: Steam Power Plant

**MW = 10^6 watts

Therefore: $150\ (1+y)^n - 150 = 52$. $(1+y)^n = 1.347$, where

y = rate of load growth; n = time period of growth, 150 = current

power demand.

For $y = 6\%$, n 5 years, $(1+y)^n = 1.338$
Thus with a 6% annual load growth new plant should go on stream within 5 years.

For $y = 5\%$, n 6 years, $(1+y)^n = 1.340$
Thus with a 5% annual load growth new plant should go on stream within 6 years.

For $y = 4.5\%$, n 7 years, $(1+y)^n = 1.361$
Thus with a 4.5% annual load growth new plant should go on stream within 7 years.

For $y = 4\%$, n 7.5 years, $(1+y)^n = 1.342$
Thus with a 4% annual load growth new plant should go on stream within 7.5 years.

For $y = 3\tfrac{1}{2}\%$, n $8\tfrac{1}{2}$ years, $(1+y)^n = 1.334$
Thus with a 3½% annual load growth new plant should go on stream within 8½ years.

For $y = 3\%$, n 10 years, $(1+y)^n = 1.344$
Thus with a 3% annual load growth new plant should go on stream within 10 years.

On or about the time new plant goes on the line, the Inductance will probably be beyond economic serviceability, and should therefore be retired for salvage. This would also apply to Piti units No 2 and 3; a total of 51 MW to be retired from the system.

Furthermore, when the new plant is added the ratio of reserve generation should remain approximately equivalent as insurance against load shedding during emergencies. Thus, it is reasonable that with new plant added, outage reserve generation consist of the largest unit plus two of the next smaller units, i.e. 66 + 2(26.5) = 119 MW.

New Plant capability.

$150\ (1+y)^n +$ retired plant + reserve generation - existing plant = new plant capability, where y = % annual load growth; n = time period of load growth, years.

Expressed in numbers, new plant capability = $150\ (1+y)^n + 51 + 119 - 296 = 150\ (1+y)^n - 126$

For y = 6%, n 5 + 5*, $150 \times 1.06^{10} - 126 = 143$ MW

For y = 5%, n 6 + 5*, $150 \times 1.05^{11} - 126 = 131$ MW

For y = 4.5%, n 7 + 5*, $150 \times 1.045^{12} - 126 = 128$ MW

For y = 4%, n 7.5 + 5*, $150 \times 1.04^{12.5} - 126 = 119$ MW

For y = 3½%, n 8½ + 5*, $150 \times 1.035^{13.5} - 126 = 113$ MW

For y = 3%, n 10 + 5*, $150 \times 1.03^{15} - 126 = 108$ MW

*Years beyond on stream date of new plant until another unit must be added.

Optimizing for best results in minimizing cash flow and dollars per KW in plant investment:

a. Anticipated load growth say 5%. Do not wait out the 6-year time limit for new plant, start with the purpose in mind of new plant on stream in 4-years and include only 4-years until a second unit will be scheduled to go on stream, thus:

   $150 \times 1.05^8 - 126 = 96$ MW. Add 1 x 87 MW unit with 10% 4-hour minimum overload capability, total 95.7 MW.

b. Anticipated load growth say 4%. Reduce 7.5-year time limit to 5-years plus 5-years for second addition thus: $150 \times 1.04^{10} - 126 = 96$ MW. As in a. above add 1 x 87 MW unit with 10% 4-hour minimum overload capability, total 95.7 MW.

Continuing on the theory that power demand will increase by 5% annually; Cabras No. 4 must be on stream in 1985. Computed as indicated under "new plant capability" above:

$150\ (1.05)^{13} + 51 + 149^{*} - 392 = 91$ MW

*Reserve power computed as the new unit plus 2-units at Tanguisson.

Because of the small difference, install a second 96-MW unit to match No. 3 at the Cabras plant. With the additions as indicated Cabras will now consist of 2 x 66 MW units plus 2 x 96 MW units; a total installed capability of 324 MW. This will take care of projected power demand at 5% per annum to 1990.

Projections at the same rate of power demand beyond 1990 are computed as follows:

$150\ (1.05)^{18} + 95^{*} + 149 - 488 = 117$ MW

*Piti units No. 4 and 5 retired for salvage.

Install one new 120 MW unit on the old Piti site. This unit to be on stream early in FY-1990. It will take care of load projection to 1995.

The capacity of the new unit to be installed in 1995 is computed as follows:

$150\ (1.05)^{23} + 95 + 173^{*} - 608 = 121$ MW

*Reserve power equal to the new unit plus 2 units at Tanguisson.

Install one new 120 MW to match the first 120 MW unit. Both units to be installed on the old Piti site. This will take care of load projection at 5% to the year 2000.

III. Projected Power Generation and Fuel Oil Consumption, Island-wide Power System

a. The pattern of island-wide power generation became erratic after typhoon Pamela, affecting FY-76, 77 and 78, thereafter the rate of growth is expected to revert to a stable condition. Thus at 5% annual increase in power generation, the progression representing growth is in the form of $y(1+x)^n$, where y = preceding FY generation, x = rate of annual increase, n = number of years projected. Fuel oil heating value assumed at 147,000 Btu/gal, the approximate current value.

For FY-76, gross generation = 994×10^6 KWH.
For FY-77, gross generation is estimated at $1,018.4 \times 10^6$ KWH.
For FY-78, gross generation is estimated at $1,117.4 \times 10^6$ KWH.
Following FY-78, power production, estimated at 5% per annum, results in the following progressive growth in generation:
$1,117.4\ (1 + 0.05)^1 = 1173.3 \times 10^6$ KWH. 5-years beyond FY-78 in FY-83, generation will have reached approximately:
$1,117.4\ (1 + 0.05)^5 = 1426.1 \times 10^6$ KWHs.

b. Fuel oil consumption is projected as follows. First, however, recognition must be given to the variables involved in power generation. All plants are not equally efficient, there is also a difference in efficiency resulting from the load carried by each plant from minimum to full load. Thus the result will depend on the makeup of the mix and load carried by each plant. At the lower end of the spectrum is the power barge Impedance and the older units in the Piti plant which will produce from 10 to 11 KWH per gallon of fuel oil. At the upper end is the new Cabras steam power plant which will produce from 15 to 16 KWHs per gallon of fuel oil. Assuming normal plant maintenance routine without forced outages fuel oil consumption, based on 5% per annum increase in power generation beyond 1978, is expected to range as follows, where (Gross KWH generation) divided by (KWH/Gallon of fuel oil attainable under most favorable conditions times the proportionalty factor of the plant mix as related to the combined operational efficiencies times 42, the number of gallons in a bbl of fuel oil) = bbls of fuel oil consumed.

1) For FY-76, as indicated in a. above, gross generation = 994 x 10^6 KWH. Fuel consumed = 1,802,000 bbls No. 6 resid; 5,050 bbls diesel grade No. 2.

2) For FY-77, as indicated in a. above, projected gross generation = 1,018 x 10^6 KWH. Fuel consumed = 1,826,311 bbls No. 6 resid; 5,200 bbls diesel grade No. 2.

3) For FY-78, as indicated in a. above, projected gross generation = 1,117.4 x 10^6 KWH. Fuel consumed = 1,886,842 bbls No. 6 resid; 5,200 bbls diesel grade No. 2.

4) For FY-79: $(1,173.2 \times 10^6) / (15 \times 0.94 \times 42)$ = 1,981,087 bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

5) For FY-80: $(1,231.8 \times 10^6) / (15 \times 0.93 \times 42) = 2,102,407$ bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

6) For FY-81: $(1,293.4 \times 10^6) / (15 \times 0.92 \times 42) = 2,231,539$ bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

7) For FY-82: $(1,358.1 \times 10^6) \times (15 \times 0.92 \times 42) = 2,343,168$ bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

8) For FY-83: $(1,426.0 \times 10^6) / (15 \times 0.91 \times 42) = 2,487,354$ bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

9) For FY-84: $(1,497.4 \times 10^6) / (15 \times 0.91 \times 42) = 2,611,896$ bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

10) For FY-85: $(1,572.3 \times 10^6) / (15 \times 0.90 \times 42) = 2,773,016$ bbls of No. 6 resid; diesel fuel oil estimated at 5,200 bbls.

In the above chronology, Cabras reaches maximum utilization in FY-78. Thereafter, use of less efficient plant must be increased, resulting in a decline of the mix from 0.94 in FY-79 to 0.90 in FY-85.

The effect of operation of old inefficient plant is illustrated as follows:

In FY-80 plant mix economy will decline from 0.94 to 0.93, resulting in an increase in fuel oil consumption of $2,102,407 \left(1 - \frac{0.93}{0.94}\right) =$ 22,366 bbls of fuel oil because of decline in plant mix operation of 1-point from 0.94 in FY-1979 to 0.93 in FY-1980.

For FY-85 the excess fuel used comes to $2,773,016 \left(1 - \frac{0.90}{0.94}\right) =$ 118,000 bbls of fuel oil because of projected decline in plant mix.

operation of 4-points from 0.94 in FY-1979 to 0.90 in FY-1985.

The foregoing equates to 22,366 $(1.39464)^n$ in excess fuel, where n = years beyond FY-80, thus:

FY-80	22,366 bbls
FY-81: 22,366 (1.39464)	31,193 "
FY-82: 22,366 $(1.39464)^2$	43,502 "
FY-83: 22,366 $(1.39464)^3$	60,670 "
FY-84: 22,366 $(1.39464)^4$	84,613 "
FY-85: 22,366 $(1.39464)^5$	118,000 "
Total FY-80 thru FY-85	360,344 bbls

Fuel oil pass thru rate per KWH

GPA rates for energy for any monthly billing period shall be increased or decreased by \$0.016 per KWH for each increase of \$0.010 per million BTU in the cost of fuel for electric power generation, above \$0.44 per million BTU. Thus:

BTU/bbl x \$0.044 x 10^{-6} = cost per bbl as base without escalation.

Increase beyond \$0.44 per million BTU =

$\left(\frac{\text{Cost/bbl}}{\text{Btu/bbl}} - \$0.44\right) \times \$0.016$ = fuel oil pass thru to consumer per KWH consumed.

Example, assume fuel oil cost at \$10.00 per bbl; heat value 147,000 Btu/gal or 6,174,000 Btu/42 gal bbl:

$$\frac{\$10.00}{6,174,000} = \$1.61969/\text{m Btu}$$

$1.61969 - $0.44 = $1.17969

$1.17969 x $0.016 = $0.018875, the fuel oil pass thru per KWH consumed.

Economics of Power Generation vs Fuel Oil Cost Pass Thru

a. At 14 KWH/gal of fuel containing 147,000 BTU in heat units plant operating efficiency =

$$\frac{14 \times 3413}{147{,}000} = 32.50\%, \text{ where } 3413 = BTU_n/KWH.$$

$14 \times 42 = 588$ KWH/bbl

$147{,}000 \times 42 = 6{,}174{,}000$ BTU/bbl

$6{,}174{,}000 \times \$0.44 \times 10^{-6} = \$2.71656$/bbl, the base price, no escalation.

$$\frac{\$10.00 - \$2.71656}{588} = \$0.0123868/KWH$$

Pass thru = $0.018875/KWH

$0.018875 - $0.0123868 = $0.006568 per KWH for station, line losses and uncollectable accounts, representing 35% of the pass thru rate.

b. At 13 KWH/gal of fuel containing 147,000 BTU in heat units, plant operating efficiency =

$$\frac{13 \times 3413}{147{,}000} = 30.18\% \; ; \quad 13 \times 42 = 546 \text{ KWH/bbl}$$

$$\frac{\$10.00 - \$2.71656}{546} = \$0.01334/KWH$$

$0.01887 - $0.01334 = $0.00553/KWH for station, line losses and uncollectable accounts, representing 29% of the pass thru rate.

c. At 12 KWH/gal of fuel containing 147,000 BTU in heat units, plant operating efficiency =

$$\frac{12 \times 3413}{147{,}000} = 27.86\%$$

$$12 \times 42 = 504 \text{ KWH/bbl}$$

$$\frac{\$10.00 - \$2.71656}{504} = \$0.01445/\text{KWH}$$

$0.01887 - $0.01445 = $0.00442 per KWH for station, line losses and uncollectable accounts, representing 23% of the pass thru rate.

IV. Fuel Oil Bulk Storage Tanks

The existing fuel oil storage tanks serve as bulk storage to fuel the island-wide steam power plants, including both Navy and Guam Power Authority's installations. Tanks are located in the near vicinity of the Navy owned Piti power plant. The storage tanks including the fuel oil transfer pumping station are owned by Guam Power Authority. The pumping station transfers fuel from the main storage tanks to the island-wide steam power plants, including the pumping of fuel through the overland pipe line to the Tanguission power plant. Each of the two storage tanks has a capacity of 268,600 bbls. They are standard API cone roof type tanks, each installed within a separately diked containment area.

The storage capacity of the two tanks mentioned above will be adequate for fuel storage needs up to the time unit No. 4 is programmed for installation at the Cabras site, when consideration must be given to the installation of storage tanks No. 3 and 4 of the same capacity as existing tanks No. 1 and 2. There is ample land area within the existing site for the installation of future tanks No. 3 and 4. However, on or before the approach of the year 2000 additional land should be acquired for future fuel oil storage requirements.

The existing tanks as well as future additions can be fueled from (1) Guam Oil and Refinery Company's Agat refinery (2) direct from the Guam Oil and Refining Company's Apra Harbor fuel wharf or (3) from Navy's Apra Harbor fuel wharfs "D" and "E". However, in the latter instance a fuel pipe line must be installed from the interconnection of wharfs "D" and "E" to the bulk storage tanks.

IV-1. Life expectancy of fuel oil storage tanks and pipe lines.

Storage tanks as well as pipe lines are usually accorded a life expectancy of 40 years. This assumes that the storage tanks will be protected with anti-corrosion paint and underground pipe lines taped to resist corrosion and cathodically protected. All fuel oil pipe lines serving the Island power plants were installed within the past 3 years, except the 8-inch overland (17.5 mile) Tanguisson pipe line installed in 1969.

V. Load Growth Projection

a. Civil Economomy

The following items are believed to be of significance in projecting the load growth pattern. Percentages assigned will vary with time, but the sum total may not be too far from realization.

Population growth, including housing, public schools, utilities, etc.	1%
Improved standards of living	½%
Tourist industry	2%
Commercial enterprises	½%
Light industry	½%
Agriculture	½%
Total	5%

In the light of current efforts to achieve economy in the use of electricity, the above estimate may be a bit optimistic initially, since demand will, for a while, be offset by frugality in use of electricity.

b. Military Installations

The present military construction program calls primarily for rehabilitation of existing installations as the aftermath of typhoon Pamela. However, included in the program are the following items:

1) Under construction by Navy:

Post Office	Bowling alleys (2)
Armory	Medical/dental facility
Gymnasium	Cold storage warehouse

2) Under design by Navy:

Secondary sewage plant

Night recreational facilities

3) Under construction by Air Force (AAFB)

Commissary refrigerated warehouse

Commissary expansion

500 housing units

It is estimated that the above construction programs will result in an increase in power demand of approximately 5%. However, this may be offset somewhat initially as the result of the economy program in the use of electricity.

Since civilian and military power demands are computed as concurrent, the resultant overall system projected power demand is 5%. Presently the military contributes approximately 45% to the total power demand; civilian 55%.

The subject matter under this section has been developed from sources considered reliable. However, because of the unpredictable nature of the variables, confirmation should be obtained from the affected agency with respect to any specific developments.

V-1. Load shedding schedules.

Load shedding when necessary, because of forced outages, is accomplished by means of outage rotation within roughly three of Guam's central metropolitan areas in equal on/off hourly periods. There are no power interruptable facilities on Guam for either short or long outage periods, either military, industrial, commercial or public utility. Although the military has some emergency generation, these are for emergencies only to protect essential services.

Companies in the US get a break thru interconnection to protect each other and to reduce the cost of power plant needed only during maintenance and forced outages. This is, of course, not possible on Guam. It should be noted that scheduled maintenance outages are not of short duration, e.g. each of the boilers in the steam power plants must be shut down annually for not less than 3 weeks to accomplish essential maintenance.

Major power outages in FY-74 thru FY-76 were caused by (1) Typhoon Pamela which caused widespread damage to primary and secondary power transmission and distribution facilities (2) two direct strikes by lightning which damaged substation apparatus and (3) outages on two occasions, with damage to substations, caused by snakes crawling up into and short circuiting overhead bus installations. Remedial measures have been taken to prevent re-occurrence of short circuits by snakes in station overhead bus work.

V-1-1. Industrial Expansion and Development.

The GORCO refinery will probably expand only moderately in future years unless a foreign market can be found for gasoline, a product currently not being produced by the Guam refinery. Gasoline is marketed on Guam by Exxon and Mobil; demand is not sufficient to warrant local production. Assuming Saipan and other Mariana Islands were included, this still would not suffice in quantity for economical production by the Guam refinery. If foreign marketing for long term sales could be developed, the Guam Oil & Refining Company has ample real estate for expansion of refining facilities to 200,000 bbls of products per day.

Air Travel Potential

Guam is acknowledged to be strategically located with respect to air travel in the South Pacific. Thus Guam is in a fortunate position to benefit through service oriented logistics for air travel. The research needed for projection of future facilities to support traffic growth, including possible need for relocation of the airport to permit expansion in a less congested area is beyond the scope of this report.

Mariculture as an Industry

Through support and coordination of the University of Guam Marine Laboratory, maricultural pursuits, where most favorable within the area of the Mariana Islands, could possibly be profitably developed as a viable food product industry. It is suggested that this could apply to cultivation of salt water plants as well as the growing of salt water fish and shellfish.

Horticulture products to support industry

Probably one of the many tropical products enjoying a profitable worldwide market is palm oil extracted from a species of palm tree bearing huge clusters of small nuts from which edible oil is extracted for use in homogenized filled milk, oleomargarine and a host of other food products. This species of palm is native to Africa, not the kind of coconut palm tree common to Guam and the Mariana Islands. There are of course many tropical plants grown to supply ingredients for food products, pharmaceutical preparations and other needs of industry. Research might uncover some exceptional possibilities.

VI. Guam Oil and Refining Company Production Estimate***

Fiscal Year	Throughput	Fuel Oil Yield	BBL/Day	Clean Products*
1977	30,000	25%	7,500	22,500
1978	35,000	45%	15,750	19,250
1979	40,000	45%	18,000	22,000
1982**	50,000	45%	22,500	27,500

*Clean Product Approximation

Fuel oil, light	43%	JP-4	26%
DFM	19%	JP-5	10%
Asphalt	1.9%	LPG	0.1%
			100.0%

**Since future market conditions are unpredictable, estimates beyond 1982 would have no meaningful connotation.

***Because of the unpredictable nature of the variables, confirmation should be obtained from Guam Oil and Refining Company respecting any specific development.

VII. Solar Sea Power

Guam is probably one of the world's most favorable sites for the development of solar sea power. The following papers are submitted herewith to illustrate feasibility of solar sea power as an alternate source of energy:

a. Letter prepared by the writer, dated 19 August 1974 with inclosure depicting temperature profiles, addressed to the Honorable Antonio B. Won Pat, Congress of the United States. Incl No. 1

b. Ocean Thermal Power Plant proposed for the Island of Nauru by Mitsui & Company, Tokyo, Japan. Incl No. 2

It is believed that the above papers are sufficient corroborating evidence of the viability of Solar Sea Power development as an alternate source of power for the Island of Guam, USA.

The bathymetric chart, Geology and Hydrology of Guam, Mariana Islands, US Geology Survey 403B:31-B76, part of incl. No. 1, indicates very favorable submarine profiles for location of land based solar sea power generators in the vicinity of the Cabreas Steam Power Plant site, southwesterly off Cocos Island or just off Facpi point, south of Nimitz Beach. In the case of a site near the Cabras Power Plant the old Navy quarry site might conceivably be set aside pending decision of feasibility studies.

VII-1. Tide current generators.

It is believed that studies of tidal flow in narrow channels between islands or submerged reefs may reveal areas where tide flow generators would be feasible and practicable for the generation of power. Tide flow would, of course, be variable in direction and magnitude, nevertheless, it is believed that where currents are pronounced a considerable amount of power could be generated during each tidal cycle. Research and exploratory work might well be worth the effort.

Mr. [illegible]

GUAM POWER AUTHORITY
P. O. BOX 2977
AGANA, GUAM 96910

August 19, 1974

The Honorable Antonio B. Won Pat
216 Cannon House Office Bldg.
Congress of the United States
House of Representatives
Washington, D.C. 20515

Dear Congressman Won Pat:

The purpose of this letter is to enlist government interest in seriously considering the Island of Guam as potentially advantageous for development of solar sea power. Because of its pollution free and self-renewing characteristics solar sea power has taken on added importance as a source of energy totally independent of fossil or atomic fuel.

Thus for the purpose of showing the potential possibilities of development of solar sea power on Guam, we are enclosing thermal profiles of sea water temperatures from surface to a depth of 3000 feet. Although the temperatures were measured at 2.5 and 3.5 miles from the shore, it is felt that it would be practicable to come close enough to land for construction of a shore based station without sacrificing too much in terms of reducing the temperature differential. For example, the charts show that at a depth of 1500 to 2000 ft temperature changes diminish rapidly with the result that within this range depth would probably bottom out at an optimized break even point. Thus at 82° F surface water and 45° F at a depth of 1500/2000 ft the differential would be 37° F. We believe that this compares favorably with conditions prevailing in other tropical zones. Another favorable factor is that the waters surrounding Guam remain markedly constant in the 82/85° F range throughout the year.

The Japanese are presently contemplating the installation of two (2) 10 MW land based solar sea power generating units on the Island of Nauru in the South Pacific for the Nauruan government as a continuous source of 10 MW (1-unit standby), sufficient for all Island Power needs. Also of special interest is the fact that cold water from the depths of the sea is extremely rich in nutrients

ENCLOSURE NUMBER 1

and that shell fish will grow very fast in feeding on the micro-organisms contained therein. Thus after serving the purpose as the condensing medium (heat sink) for power generation, the warmed water could serve to support a maricultural industry. Given time for development, this could result in a major food production enterprise for the Island of Guam.

It is our premise that the potential possibilities here on Guam for the development of solar sea power may be better or approximately equal to other potential sites in tropical areas where such developments hold promise of practicability. We, therefore, respectfully request the cooperation of your good office in placing this petition for the consideration of Guam as a potential site for solar energy development in the hands of those who have been designated as agencies of the government to research, promote and implement this source of inexhaustable energy.

In view of the encouraging potential possibilities for development of solar power on Guam, your early attention to the foregoing will be greatly appreciated.

Respectfully,

E. W. SCHAARDT
Chairman, Board of Directors

EWS/WFP/tmd

Enclosure

University of Guam Marine Laboratory

July 24, 1974

Mr. Walter Pinckert
Guam Power Authority
Gabriel Building
Agana, Guam

Dear Mr. Pinckert:

Enclosed are the two temperature profiles that you requested from the Cabras Island and Tanguisson Point Station. Station 28 was taken offshore from the Tanguisson Power Plant site. A contiuous series of bearings taken during the profile operation places its position at 13°34'48" N and 144°43'36" E (center of seven plots). Station 29 was taken offshore from Cabras Island. A continuous series of bearings taken during the profile operation places its position at 13°30'12" N and 144°39'30" E (center of seven plots).

Table 1 shows the actual depths sampled (in meters and feet) and the corrected temperatures in (°)C.

Enclosed also are 12 expendable bathythermograph profiles that were taken on April 7 and 8, 1973, from a Chinese research vessel "Chiu Lein". These profiles were drawn directly from the recorder graphs. The approximate positions of these profiles are shown on a bathymetric chart that has been taken from Emory (1962). The positions of lat. and long. shown on the graphs themselves were computed from a satalite navagation system on board the "Chiu Lein" and are much more accurate. The positions of the expendable bathythermographs as well as the two deeper plots can be plotted on the U.S. Hydrographic Map No. 4196 that you have in your office. All of these profiles show a remarkably constant layer of warm 82° F. water which varies in depth from about 300 to 400 feet. The temperature drops at an increasing rate from the 82° F. water to 45°-50° F. at about 1500 feet in depth.

I have also enclosed a xeroxed copy of some offshore submarine profiles that were taken by Emery (1962) around the island, Most of the submarine profiles are not deep enough but they give you some idea of the island slopes.

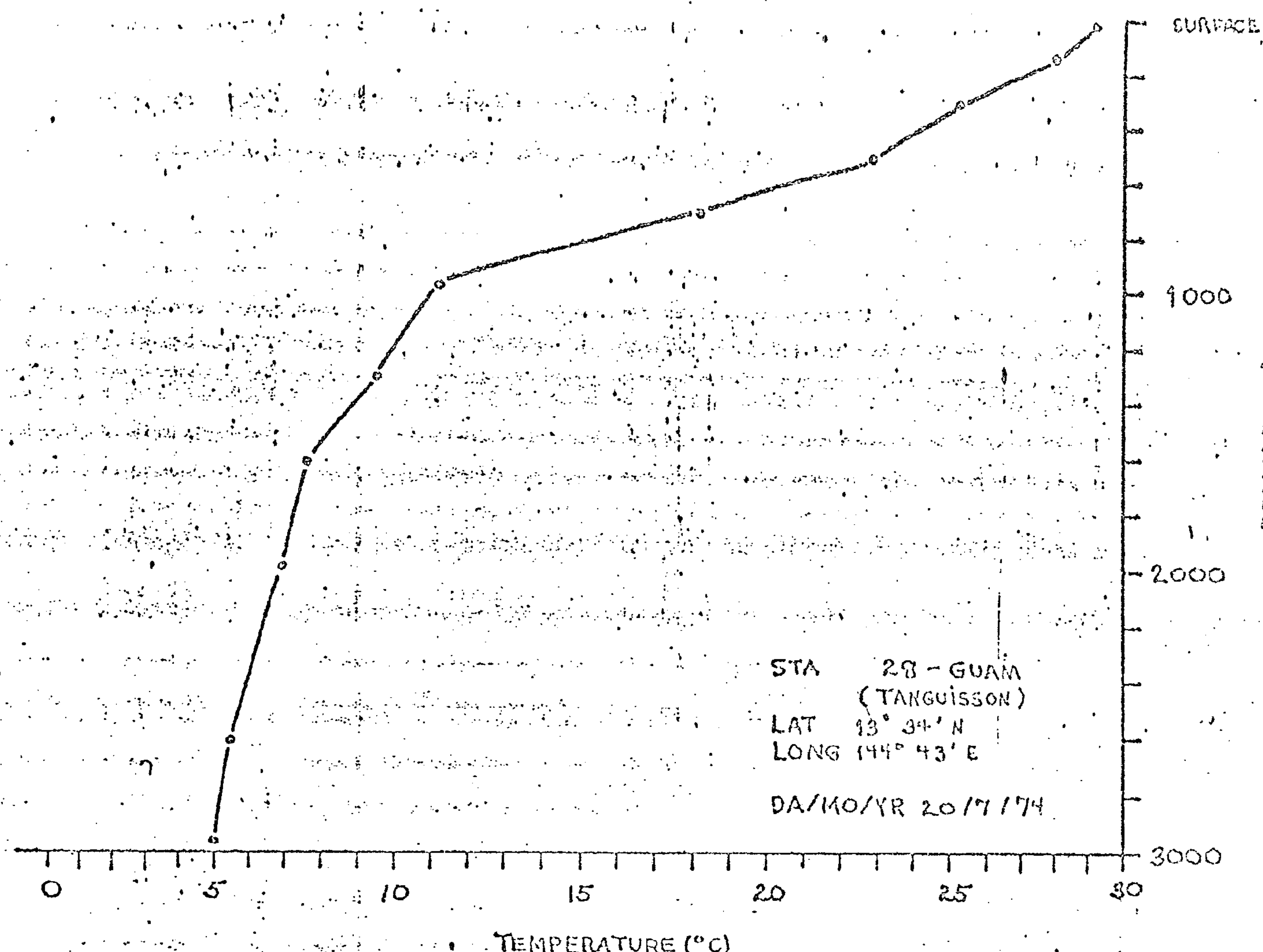
From the bathymetric map you can see that the 3000 foot submarine contour is much closer to the island at Cabras Island than at the Tanguisson site. From the preliminary data it looks as if the temperature regime that you are looking for is found around the Cabras site at feasible depths.

If you need any additional information or wish to discuss the results please call or contact me at the Marine Laboratory.

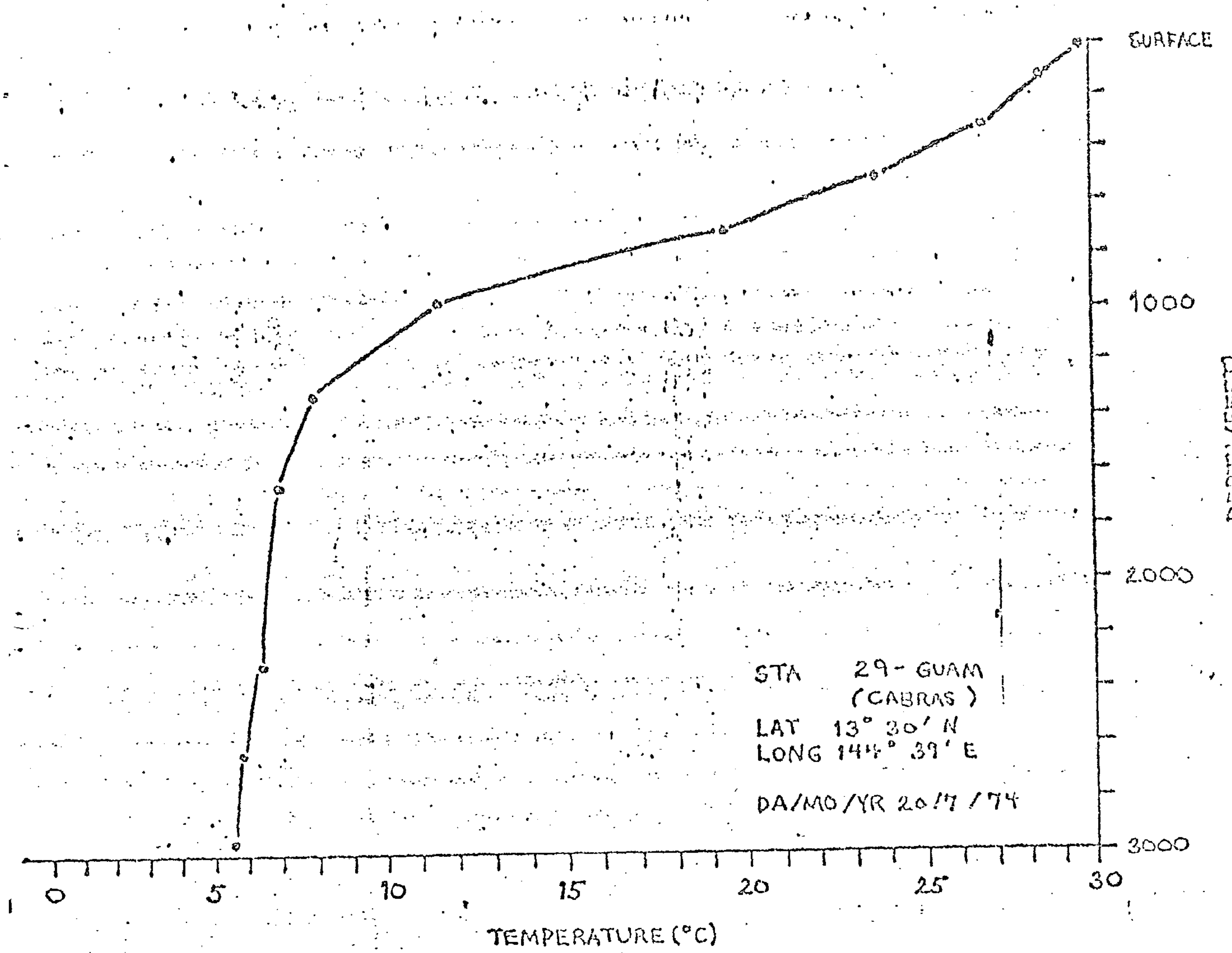
Yours sincerely,

Richard H. Randall

Richard H. Randall



SURFACE
1000
2000
3000
DEPTH (FEET)
STA 28 - GUAM
(TANGUISSON)
LAT 13° 34' N
LONG 144° 43' E
DA/MO/YR 20/7/74
0
5
10
15
20
25
30
TEMPERATURE (°C)



SURFACE
1000
2000
3000
DEPTH (FEET)
STA 29- GUAM
(CABRAS)
LAT 13° 30' N
LONG 144° 39' E
DA/MO/YR 20/7/74
0
5
10
15
20
25
30
TEMPERATURE (°C)

Tablo 1. Depths and corrected temperaturos for Profiles 28 and 29.

Cabras Island Sito No. 29

Depth		Temperature	
meters	foot	uncorrected	corrected
890	2920	6.1	5.7
890	2920	5.9	5.5
800	2625	6.3	5.9
700	2297	6.9	6.5
500	1640	7.4	7.0
400	1312	8.5	8.1
300	984	11.9	11.6
200	656	19.7	19.5
150	492	23.9	23.8
100	328	26.8	26.7
50	164	28.5	28.5
surface	surface	29.7	29.7

Tanguisson Point Site No. 28.

890	2920	5.6	5.1
890	2920	5.1	4.6
800	2625	5.8	5.3
600	1968	7.3	6.9
500	1640	8.0	7.6
400	1312	9.9	9.5
300	984	11.6	11.3
200	656	18.8	18.6
150	492	22.8	22.7
100	328	25.5	25.4
50	164	28.0	27.9
surface	surface	29.2	29.2

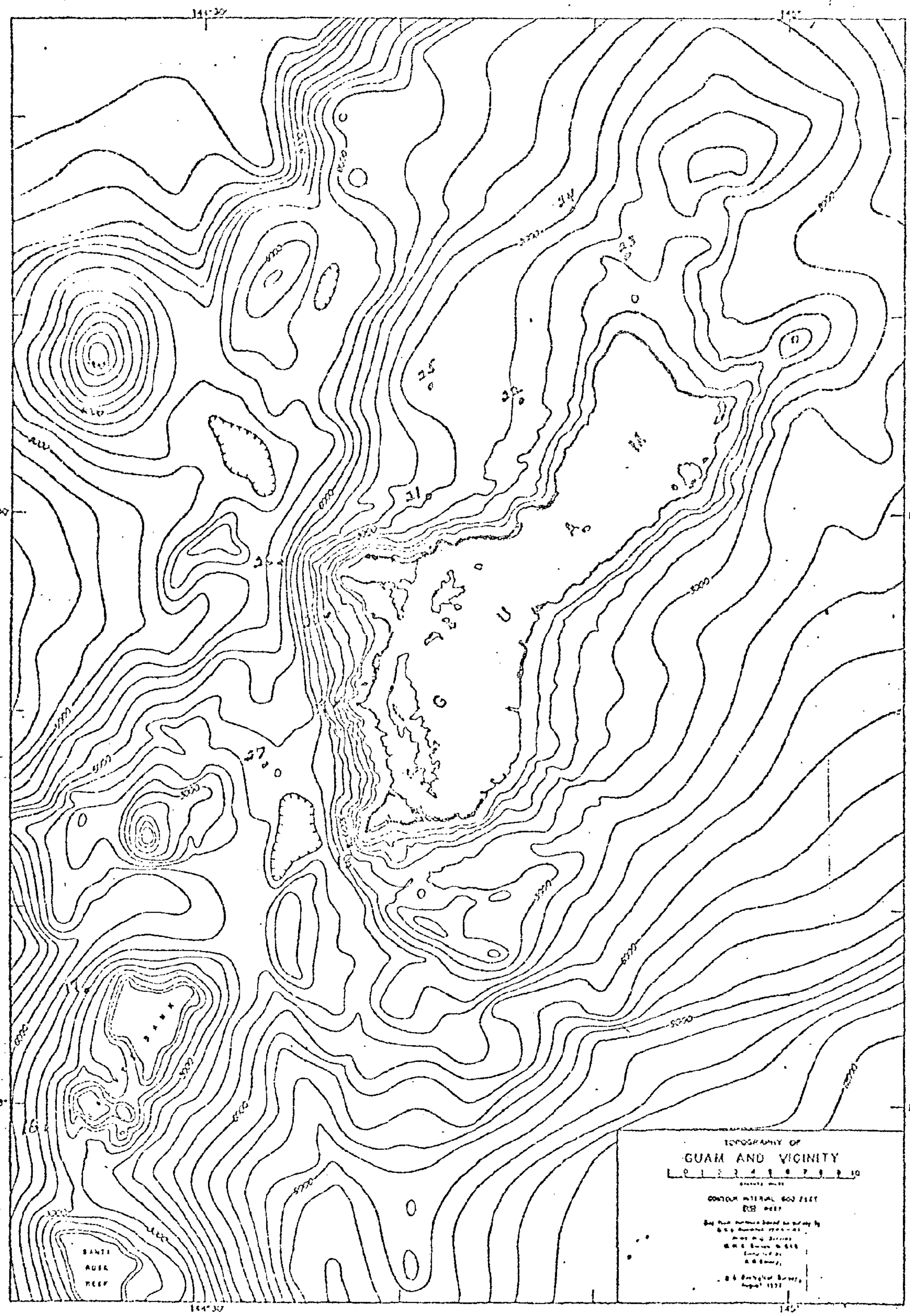
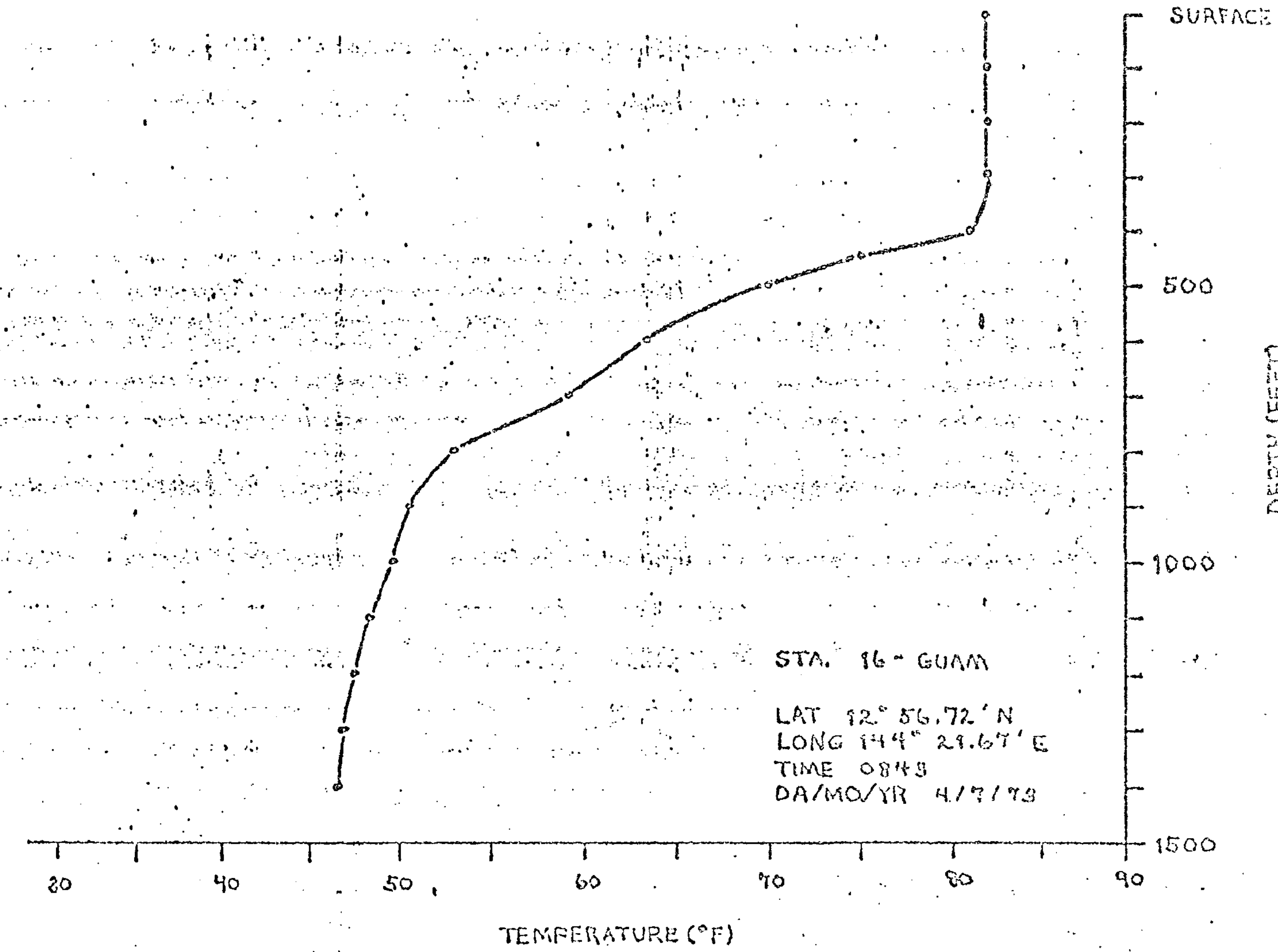
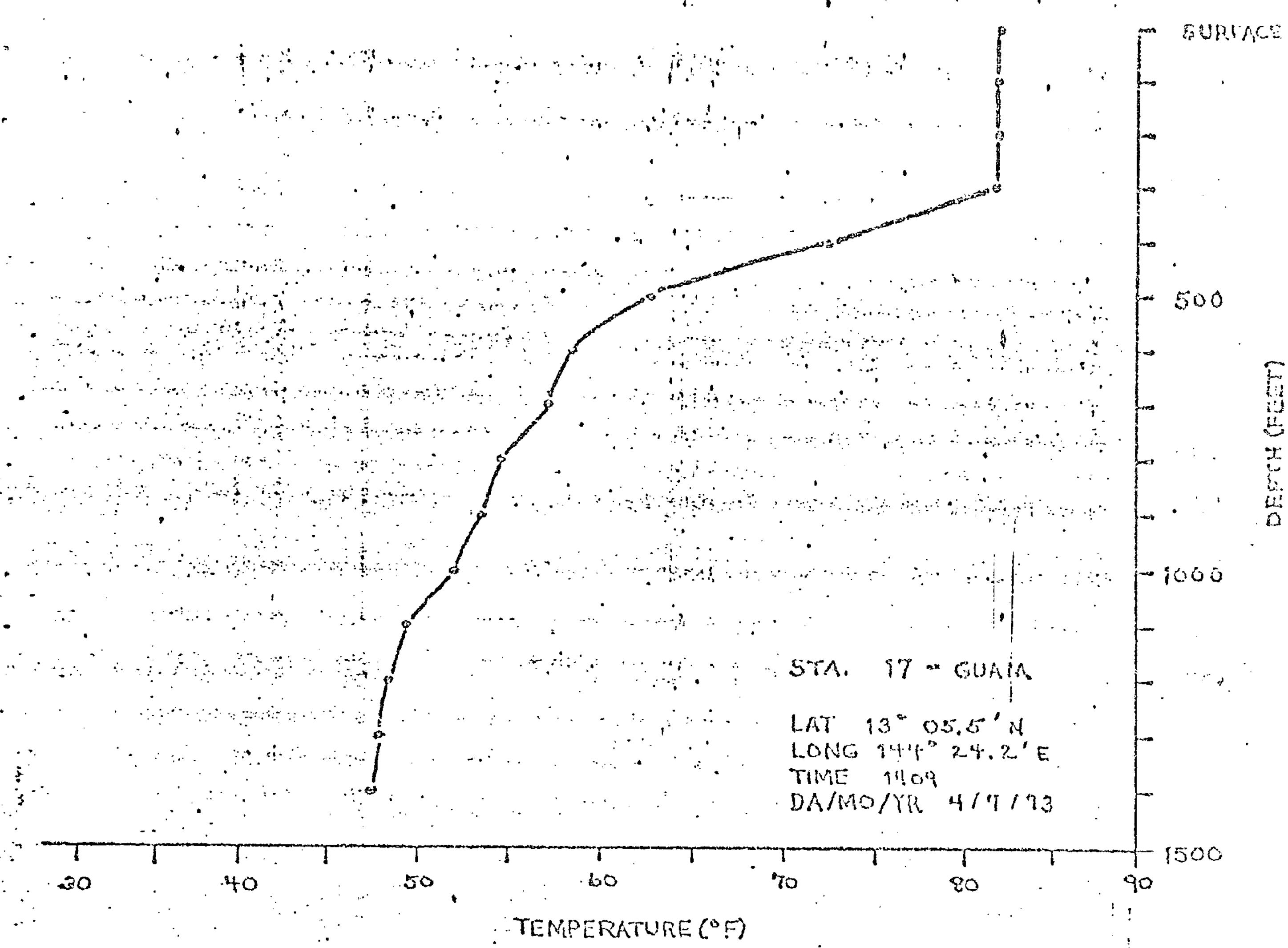


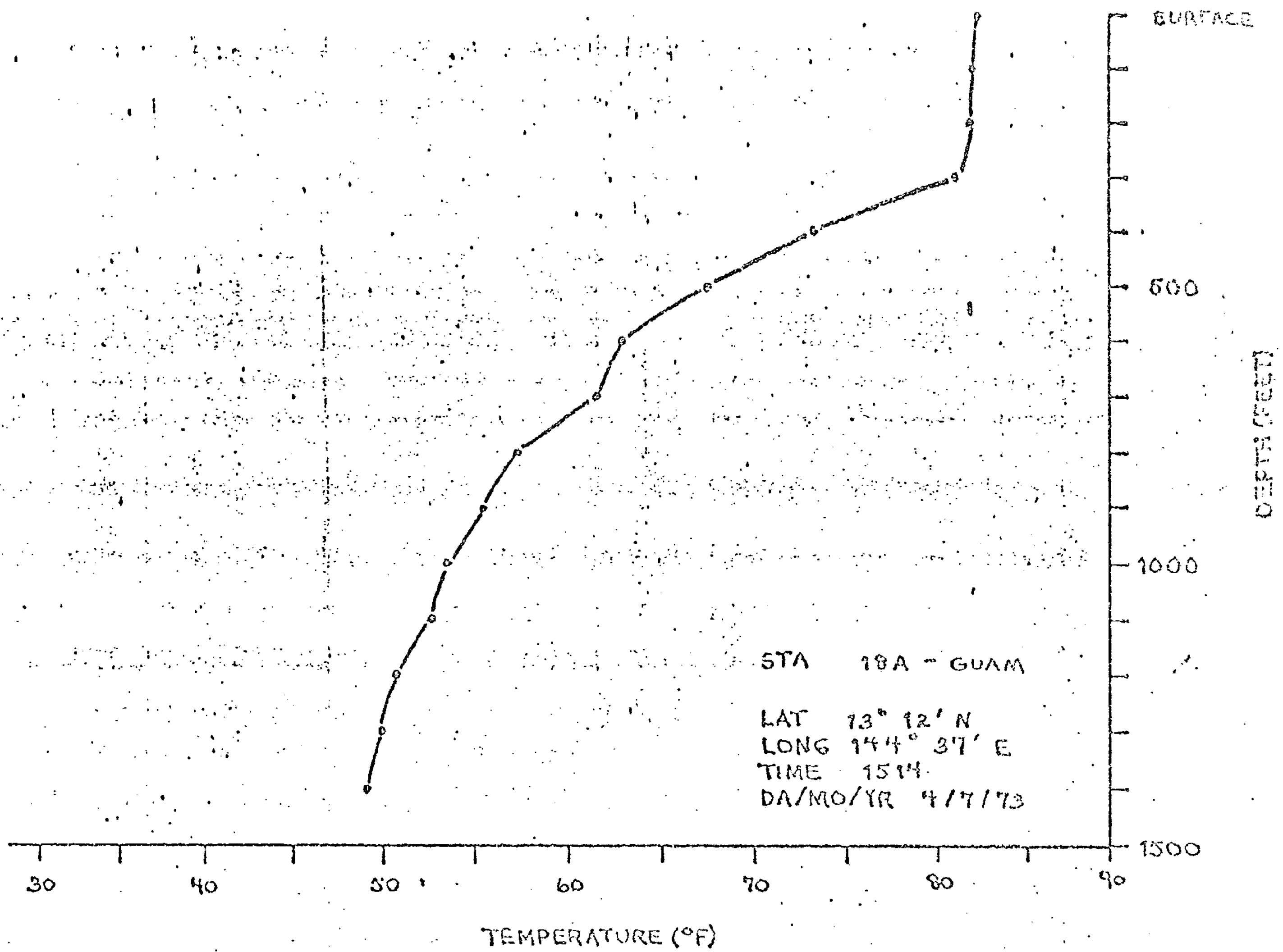
FIGURE 8.—Bathymetric chart of Guam and vicinity. Contour interval is 600 feet (100 fathoms) on both land and sea floor. Reef areas shown by solid black pattern.

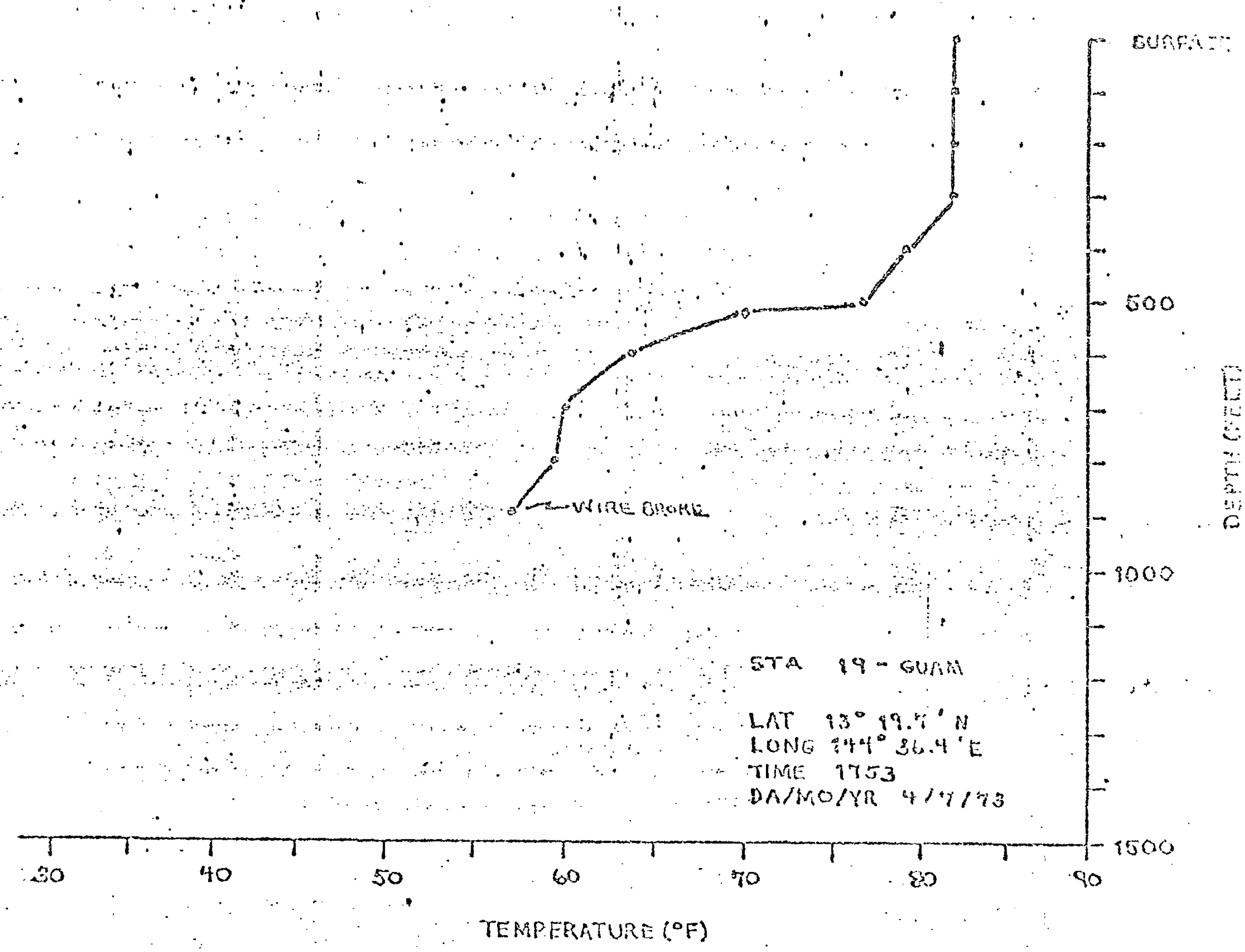
Figure from:

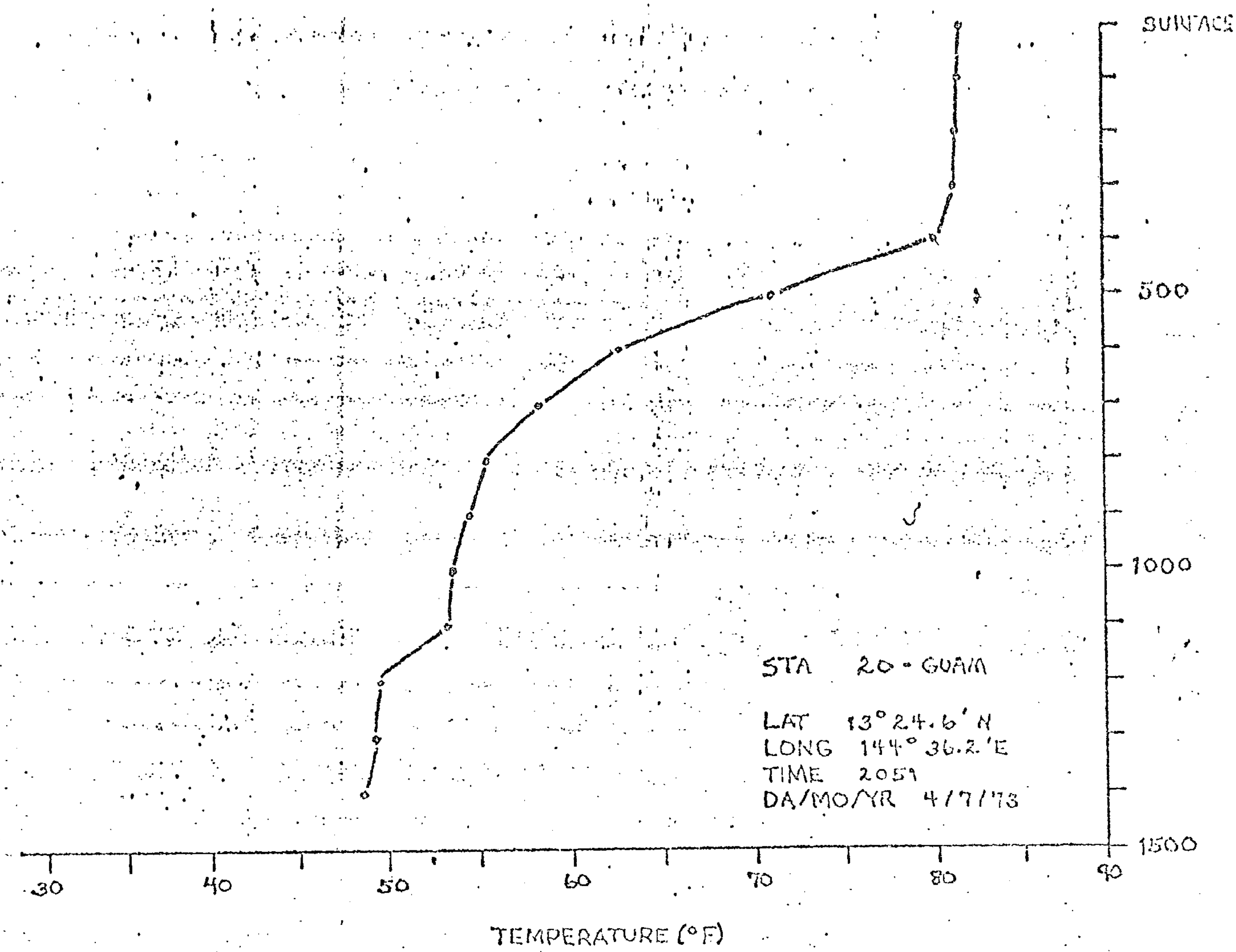
Emery, K. O. 1962. Marine geology of Guam. U. S. Geol. Survey Prof. Pap. 403B:B1-B76.

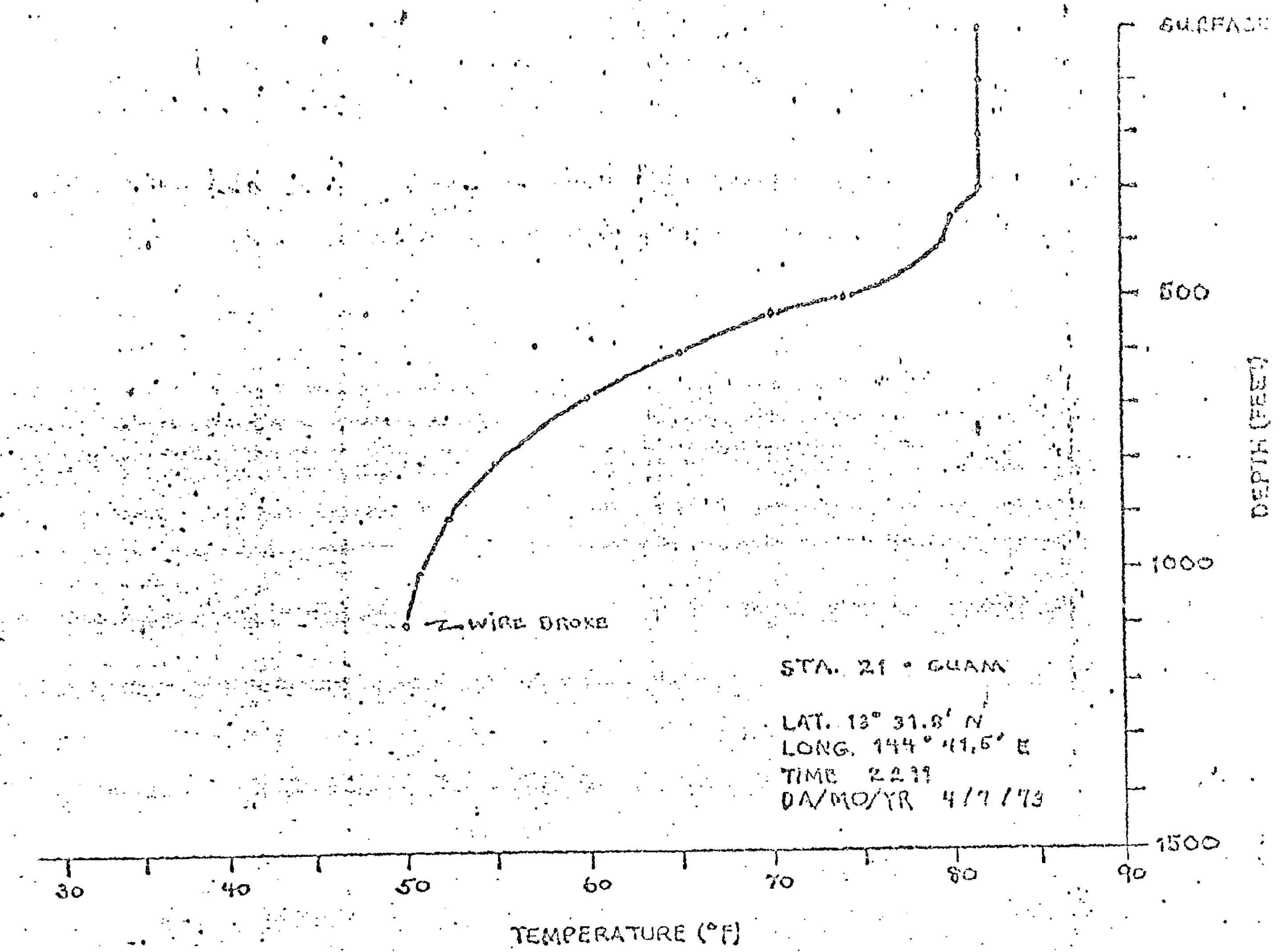

SURFACE
500
1000
1500
DEPTH (FEET)
STA. 16 - GUAM
LAT 12° 56.72' N
LONG 144° 21.67' E
TIME 0849
DA/MO/YR 4/7/73
30
40
50
60
70
80
90
TEMPERATURE (°F)


SURFACE
500
1000
1500
DEPTH (FEET)
STA. 17 - GUAM
LAT 13° 05.5' N
LONG 144° 24.2' E
TIME 1409
DA/MO/YR 4/7/73
30
40
50
60
70
80
90
TEMPERATURE (°F)

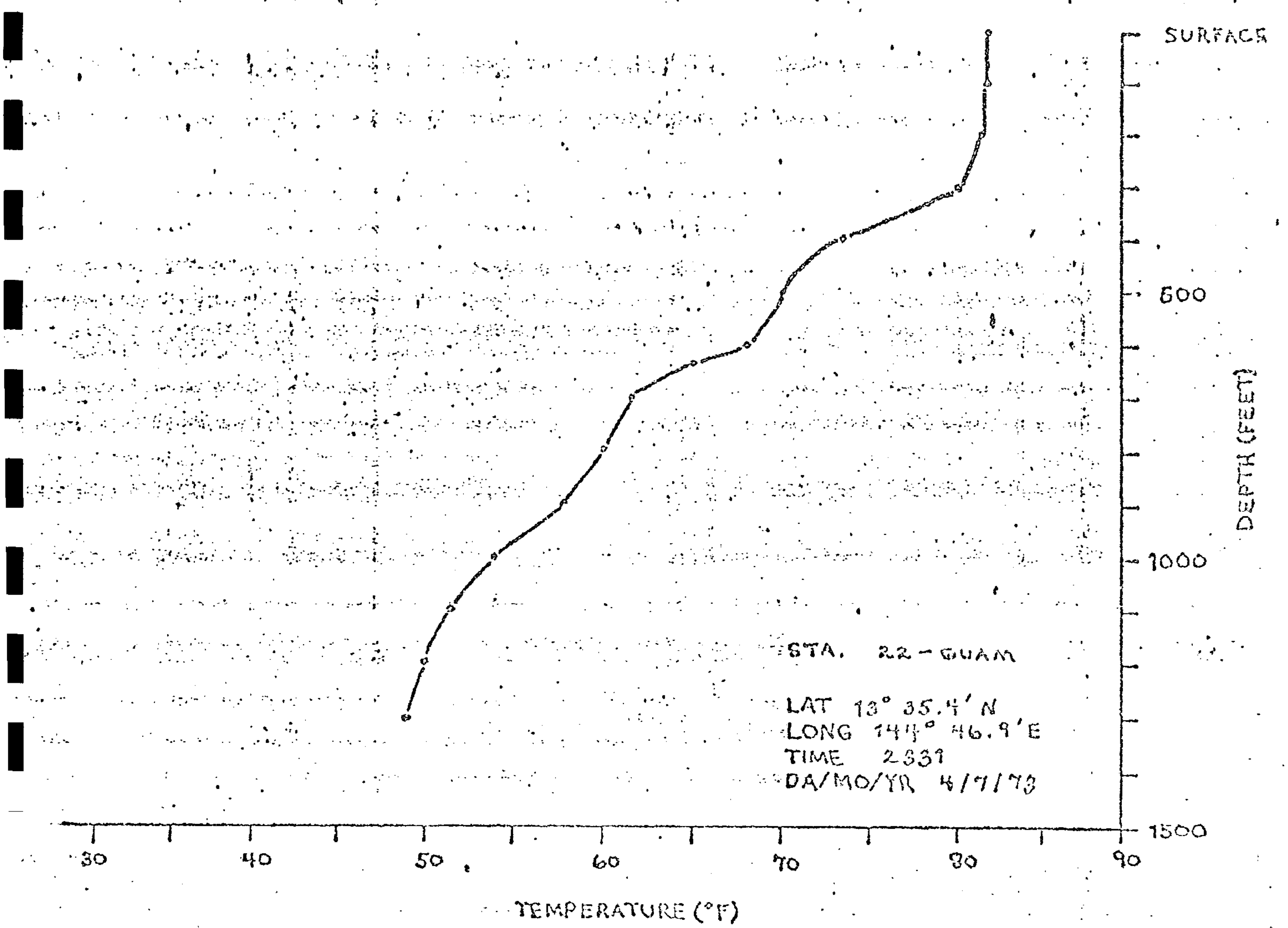

SURFACE
500
1000
1500
DEPTH (FEET)
STA 18A - GUAM
LAT 13° 12' N
LONG 144° 37' E
TIME 1514
DA/MO/YR 4/7/73
30
40
50
60
70
80
90
TEMPERATURE (°F)

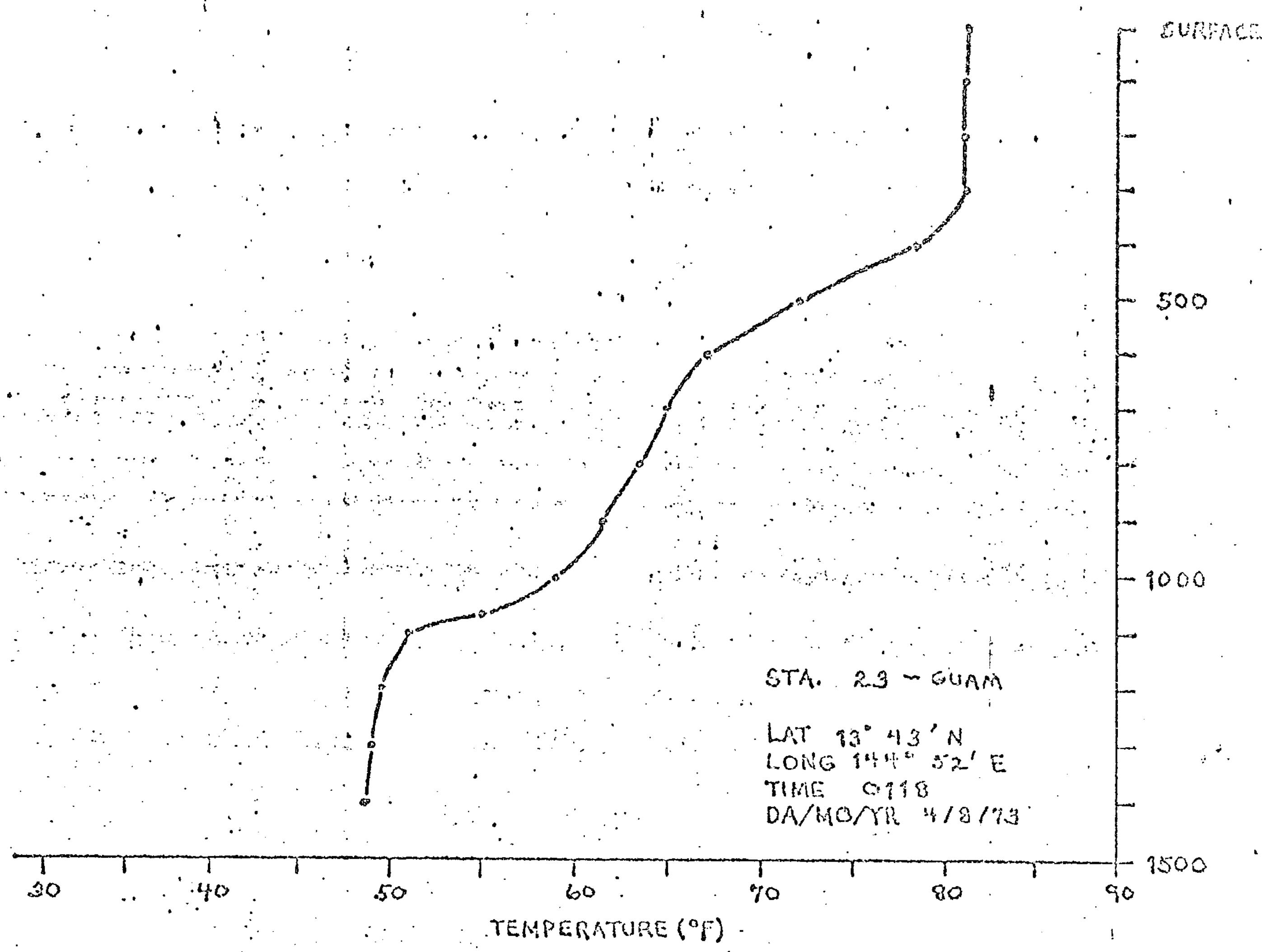

SURFACE
500
1000
1500
DEPTH (FEET)
WIRE BROKE
STA 19 - GUAM
LAT 13° 19.7' N
LONG 144° 36.4' E
TIME 1753
DA/MO/YR 4/7/73
30
40
50
60
70
80
90
TEMPERATURE (°F)

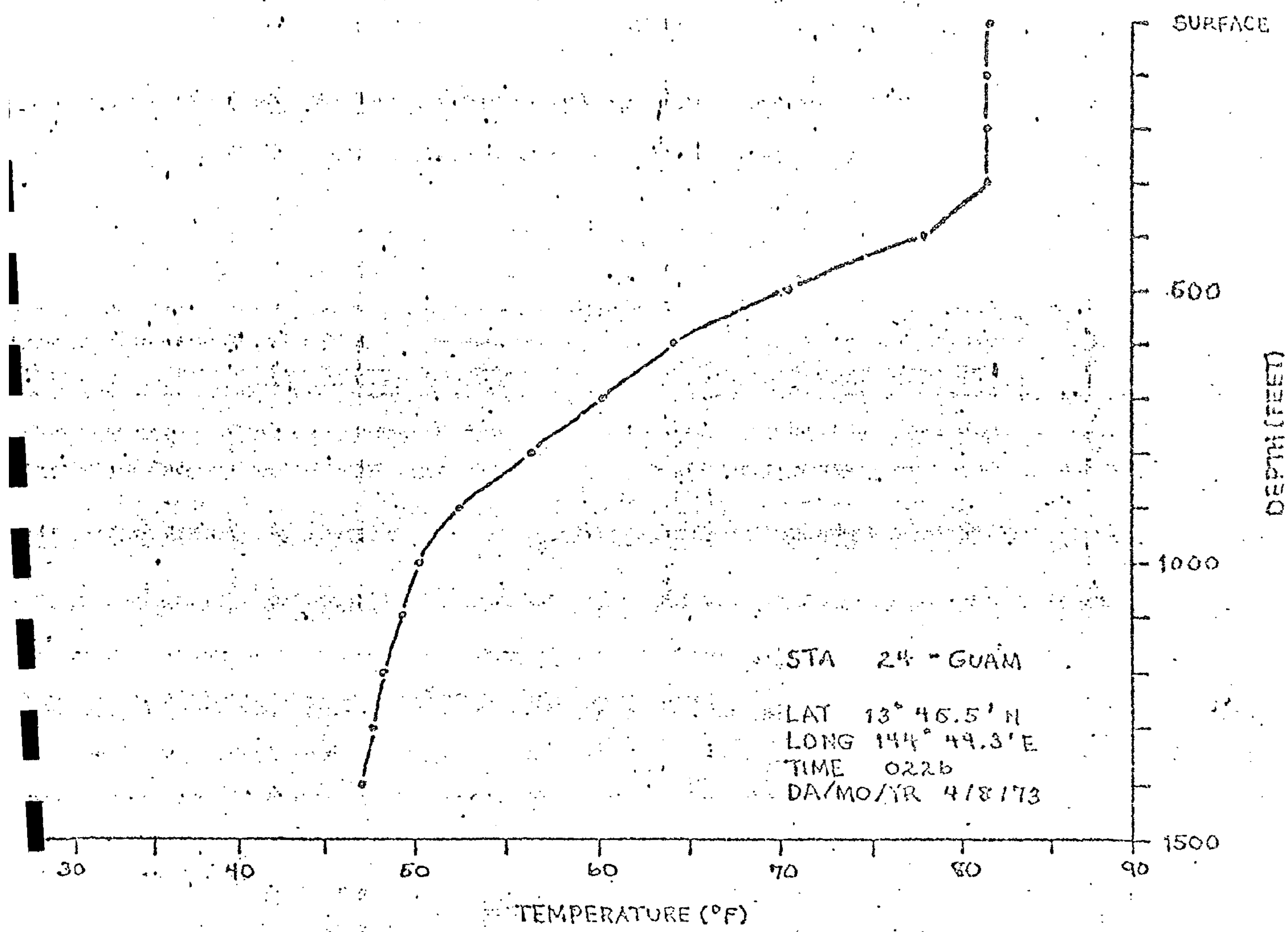

SURFACE
500
1000
1500
DEPTH (FEET)
STA 20 - GUAM
LAT 13° 24.6' N
LONG 144° 36.2' E
TIME 2059
DA/MO/YR 4/7/73
30
40
50
60
70
80
90
TEMPERATURE (°F)

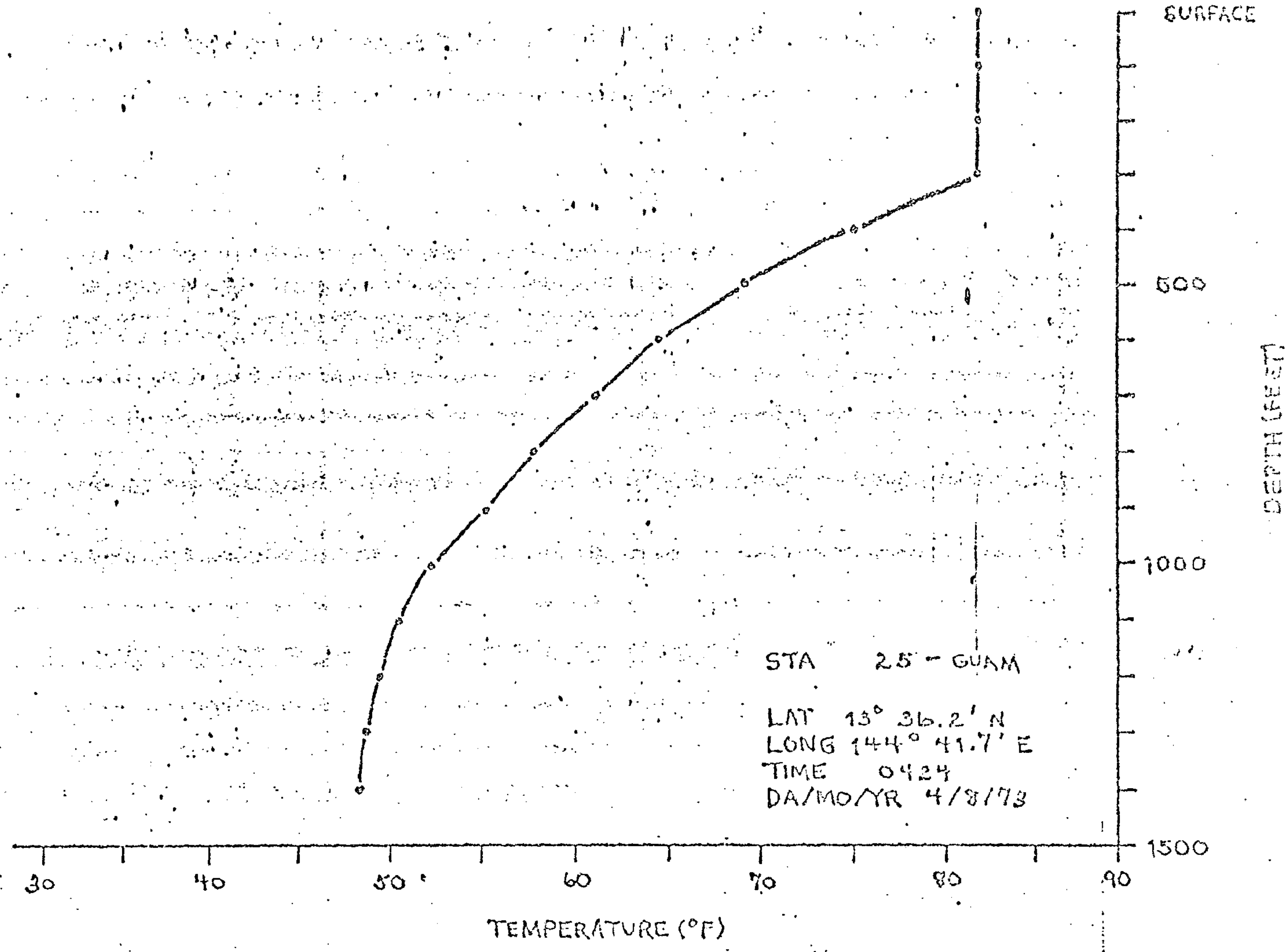


SURFACE
500
1000
1500
DEPTH (FEET)
WIRE BROKE
STA. 21 • GUAM
LAT. 13° 31.8' N
LONG. 144° 41.5' E
TIME 2211
DA/MO/YR 4/7/73
30
40
50
60
70
80
90
TEMPERATURE (°F)

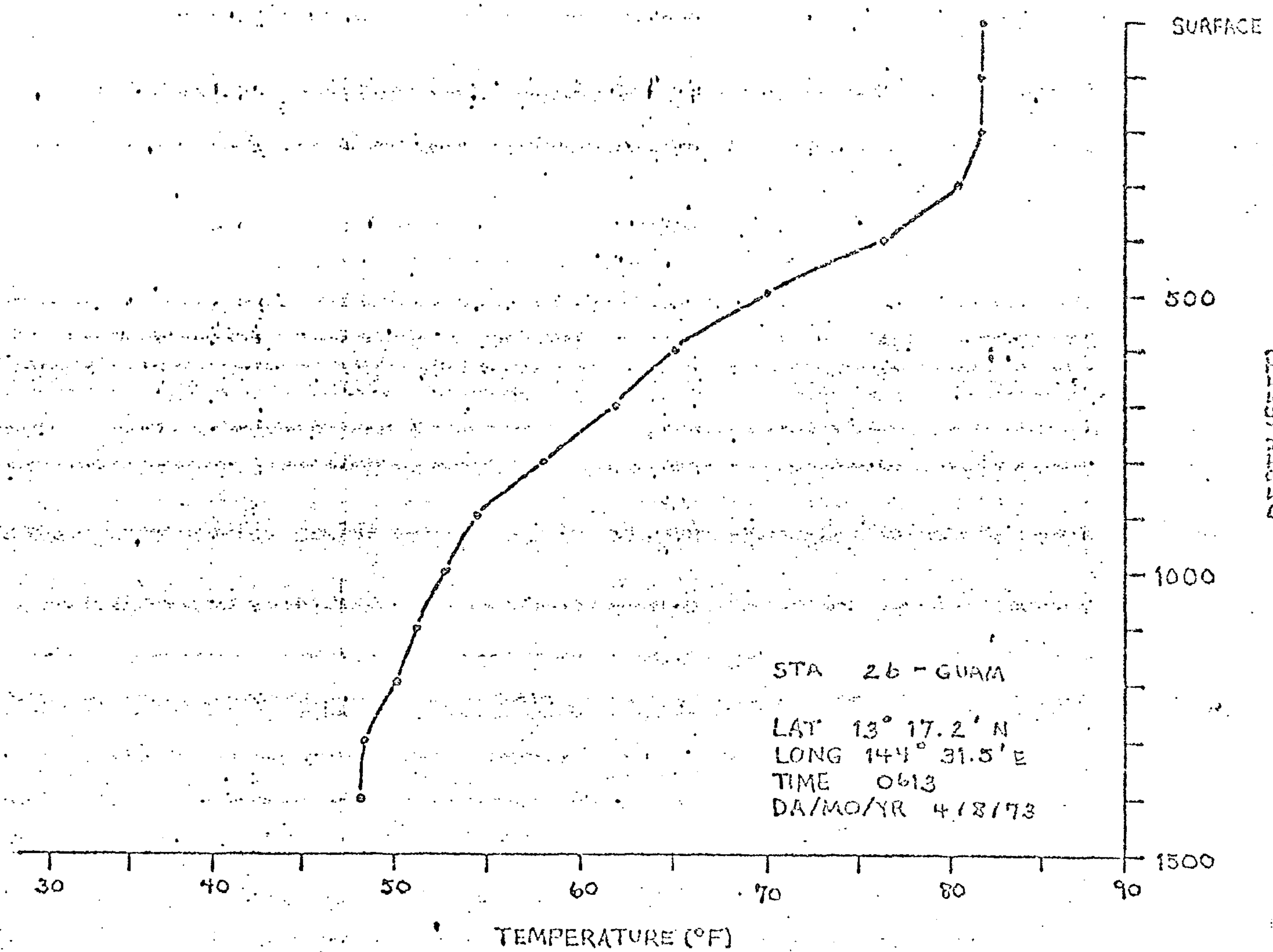

SURFACE
500
1000
1500
DEPTH (FEET)
30
40
50
60
70
80
90
TEMPERATURE (°F)
STA. 22 - GUAM
LAT 13° 35.4' N
LONG 144° 46.9' E
TIME 2331
DA/MO/YR 4/7/73

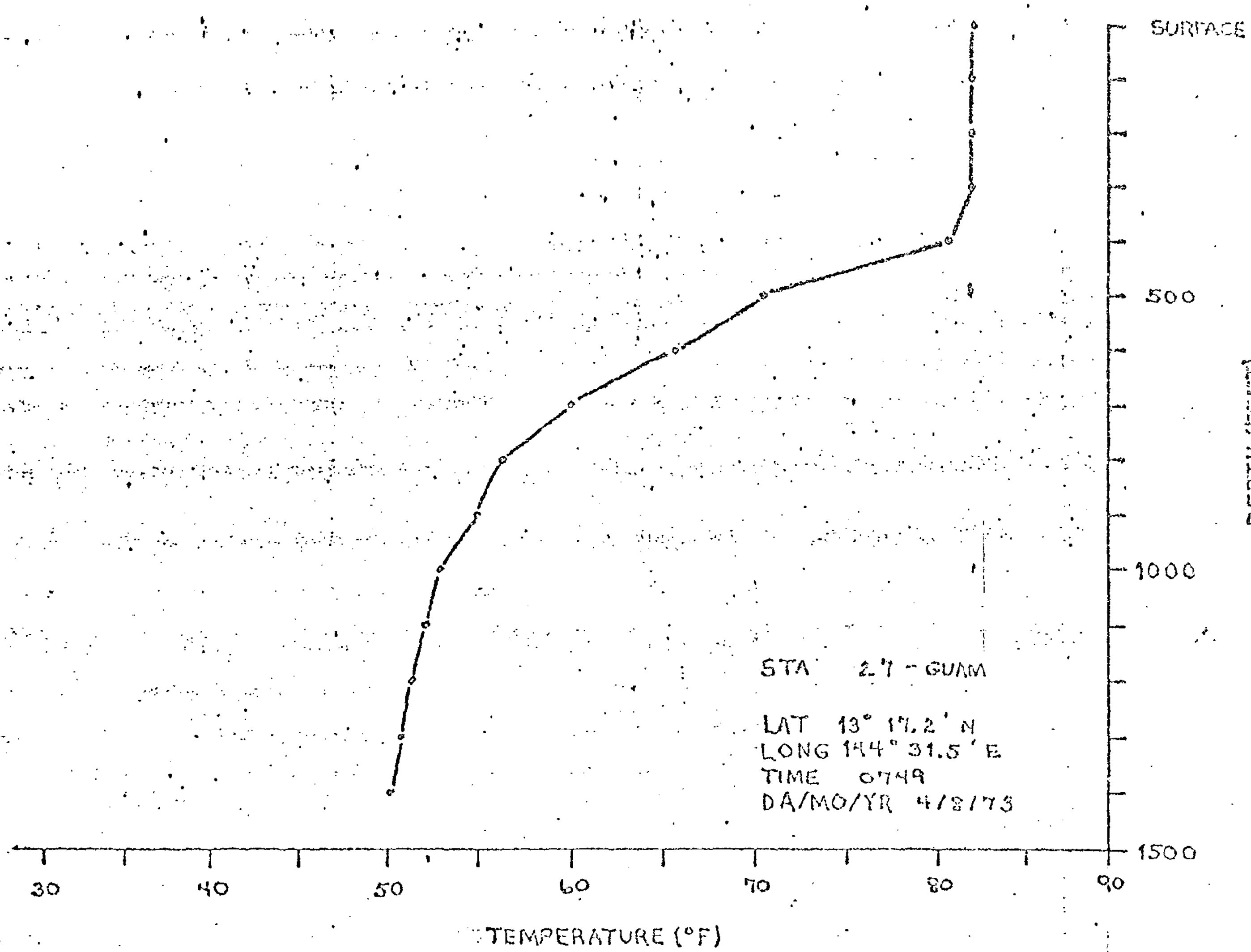

SURFACE
500
1000
1500
DEPTH (FEET)
30
40
50
60
70
80
90
TEMPERATURE (°F)
STA. 23 ~ GUAM
LAT 13° 43' N
LONG 144° 52' E
TIME 0118
DA/MO/YR 4/8/73


SURFACE
600
1000
1500
DEPTH (FEET)
STA 24 - GUAM
LAT 13° 46.5' N
LONG 144° 49.3' E
TIME 0226
DA/MO/YR 4/8/73
30
40
50
60
70
80
90
TEMPERATURE (°F)



SURFACE
500
1000
1500
DEPTH (FEET)
30
40
50
60
70
80
90
TEMPERATURE (°F)
STA 25 - GUAM
LAT 13° 36.2' N
LONG 144° 41.7' E
TIME 0424
DA/MO/YR 4/8/73


SURFACE
500
1000
1500
DEPTH (FEET)
30
40
50
60
70
80
90
TEMPERATURE (°F)
STA 26 - GUAM
LAT 13° 17.2' N
LONG 144° 31.5' E
TIME 0613
DA/MO/YR 4/8/73



SURFACE
500
1000
1500
DEPTH (FEET)
30
40
50
60
70
80
90
TEMPERATURE (°F)
STA 27 - GUAM
LAT 13° 17.2' N
LONG 144° 31.5' E
TIME 0749
DA/MO/YR 4/8/73

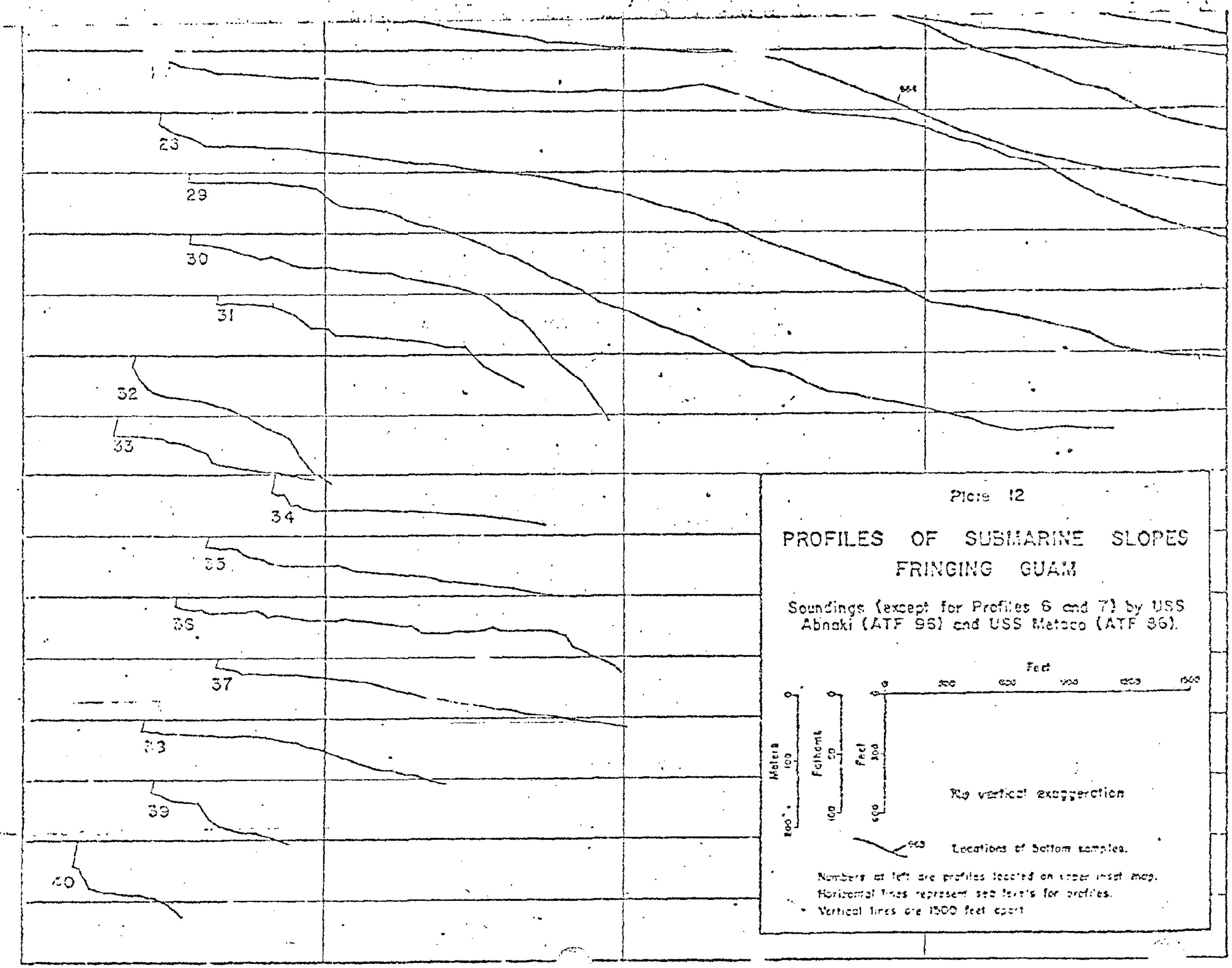
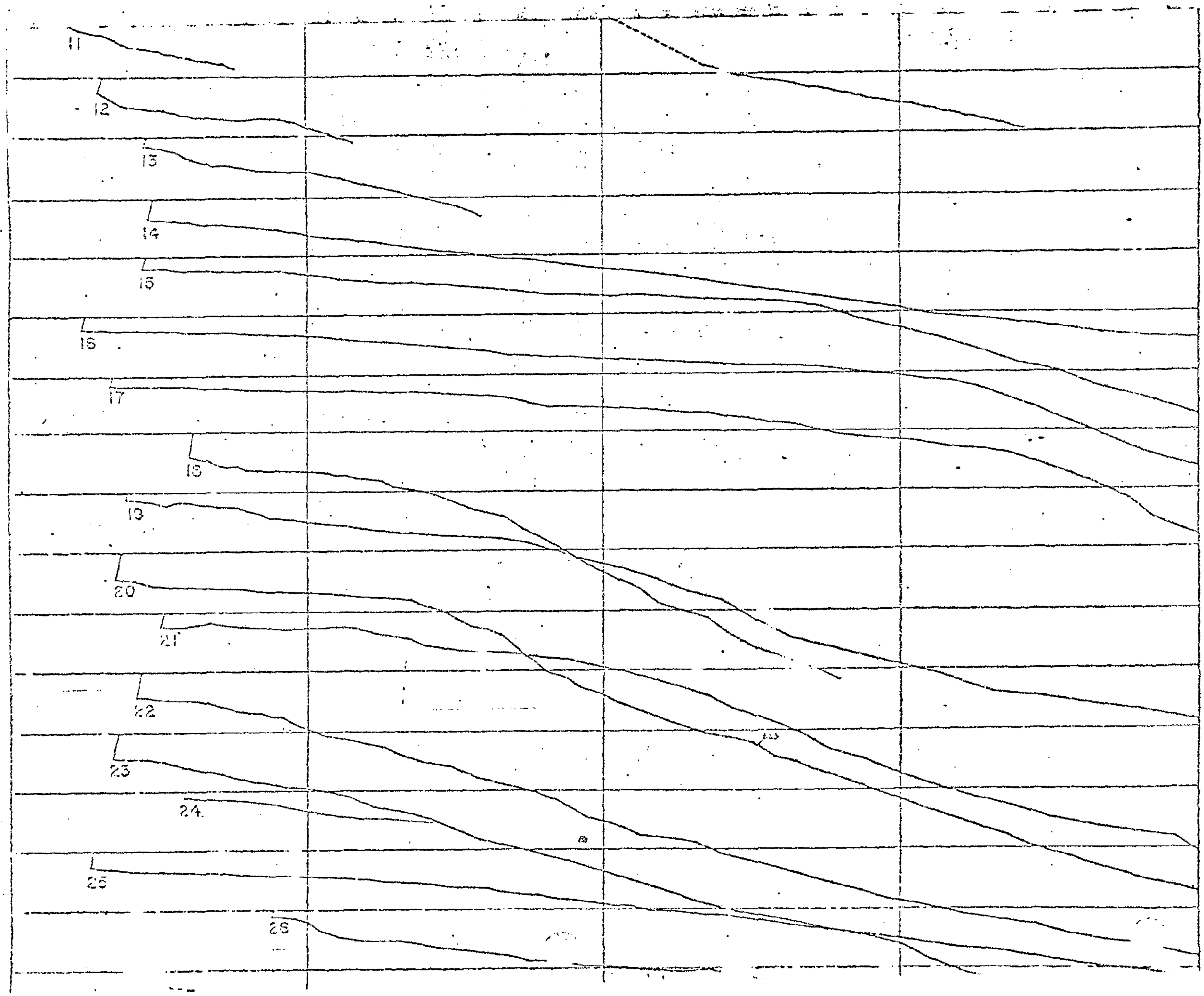
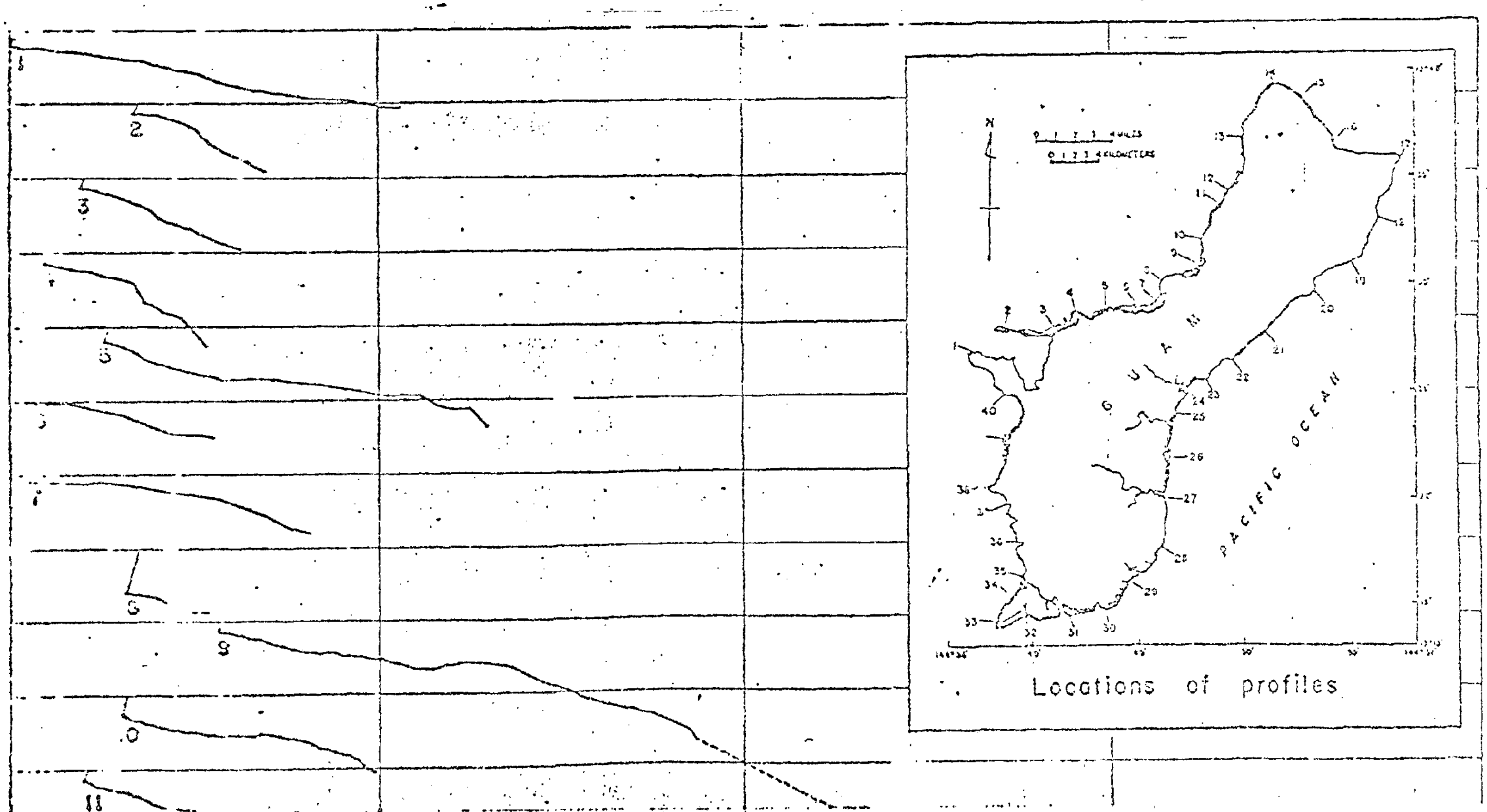


Plate 12
PROFILES OF SUBMARINE SLOPES FRINGING GUAM
Soundings (except for Profiles 6 and 7) by USS Abnaki (ATF 96) and USS Metaco (ATF 86).
Feet
0
300
600
900
1200
1500
Meters
100
200
Fathoms
50
100
Feet
300
600
No vertical exaggeration
Locations of bottom samples.
Numbers at left are profiles located on upper inset map.
Horizontal lines represent sea levels for profiles.
Vertical lines are 1500 feet apart
23
29
30
31
32
33
34
35
36
37
39



11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

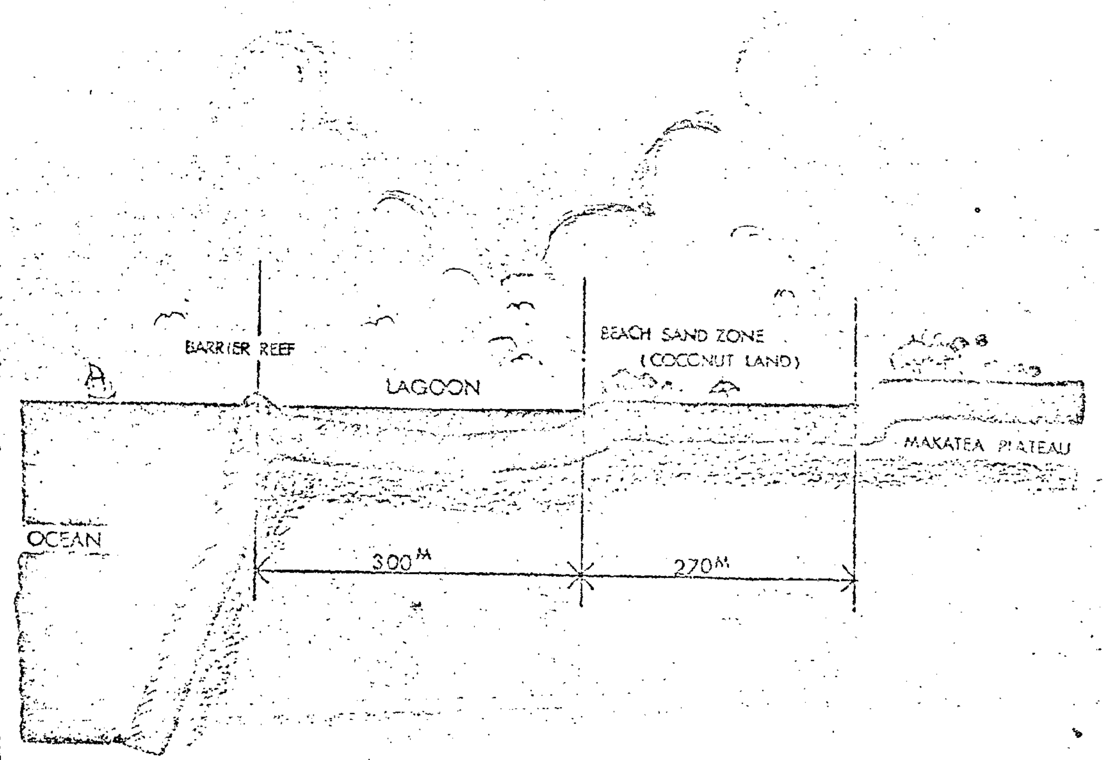
Figure from: Emery, K. O. 1962. Marine geology of Guam. U. S. Geol. Survey Prof. Pap. 403B:B1-B76.



OCEAN THERMAL POWER PLANT ON THE ISLAND

TYPICAL CROSSSECTION

OF THE ISLAND OF NAURU



NOTE

3.0 OCEAN THERMAL POWER PLANT AND ASSOCIATED FACILITIES

3.1 OCEAN THERMAL POWER PLANT

3.1.1 Capacity of an Ocean Thermal Power Generating Unit

The ocean thermal power plant will have two 10,000 Kw ocean thermal power generating units.

The unit capacity of 10,000 Kw was selected in consideration of existing system capacity of Nauru Phosphate Corporation of 8,285 Kw as of 1970.

There is no difficulty to build a much larger unit, if greater electric power demand is expected in the near future.

3.1.2 Outline of an Ocean Thermal Power Generating Unit

An ocean thermal power generating unit will have following major components;

1 - 10,000 Kw propane turbine generator set

1 - Propane gas evaporator

1 - Propane gas condenser

1 - Liquid propane pump

1 - Warm ocean water pump

1 - Cold ocean water pump

2 - Warm ocean water intake pipe line

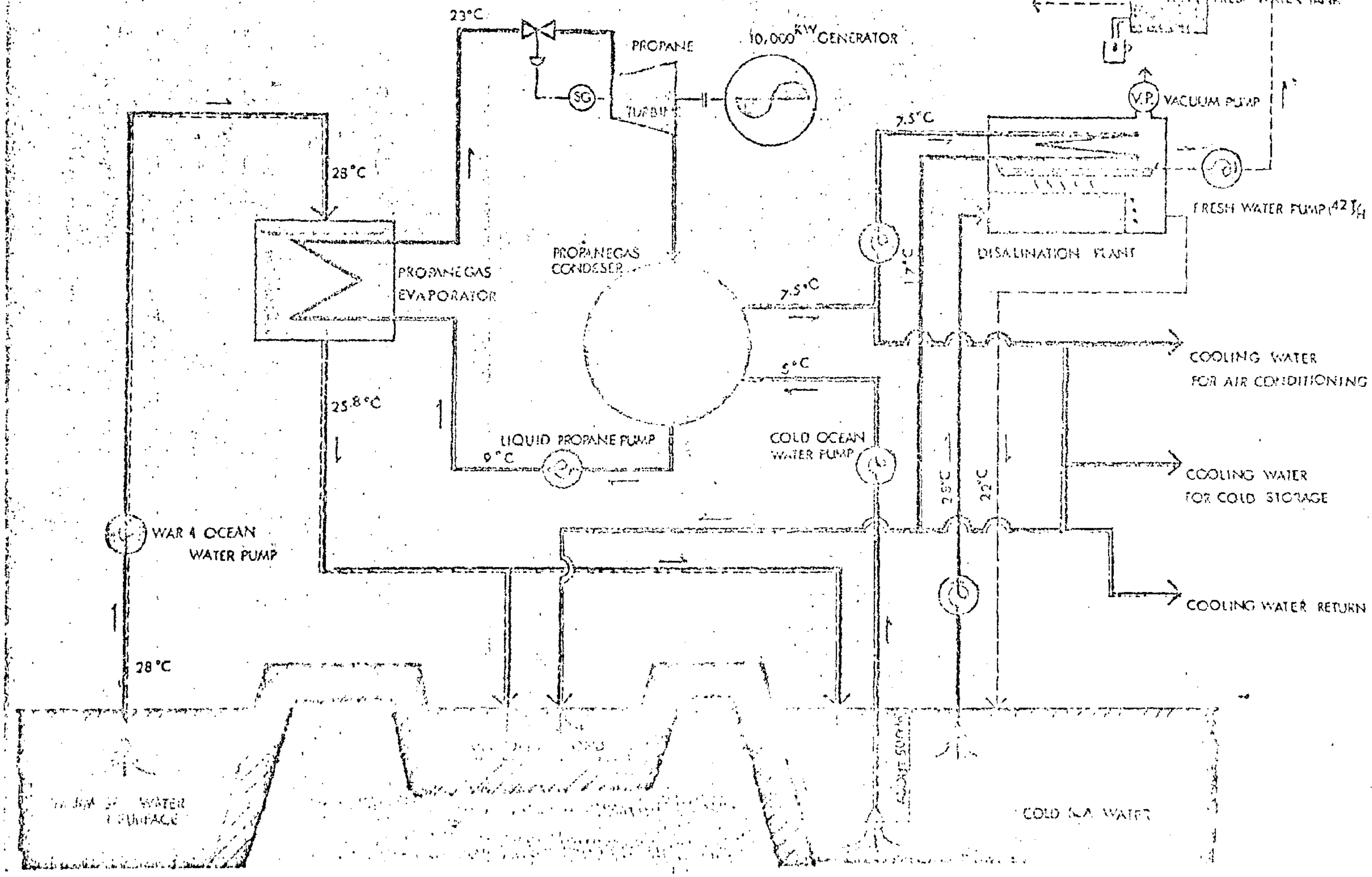
2 - Cold ocean water intake pipe line

1 - Desalination plant

1 - Fresh water storge tank

(For more details, please refer to the specification attached.)

FLOW DIAGRAM OF PROPOSED PROJECT



Warm surface ocean water at the temperature of 28°C is fed to the propane gas evaporator by the warm ocean water pump to heat the liquid propane in the evaporator and is returned to the ocean at the temperature of 25.8°C.

Liquid propane which is forced into the propane gas evaporator by a liquid propane pump at 9°C comes out of the evaporator in the form of high pressure gas at the temperature of 23°C.

High pressure gaseous propane then expands in a propane turbine giving up it's kinetic energy to drive the generator then flows into the propane condenser and condenses in it.

Cold ocean water at 5°C is fed to the propane condenser by a cold ocean water pump to cool the gaseous propane, in the propane condenser, and is discharged into a mariculture pond at 7.5°C to fertilize shells and shrimps.

Liquid propane condensed in the propane gas condenser is pressurized and fed into the propane gas evaporator by the liquid propane pump to complete a heat cycle.

5.1.3 Specification of Equipment for Nauru Ocean Thermal Power Plant

Pumps are set in the pit cut on the lagoon floor.